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Final Technical Report
December 1976

LANGUAGE CONTROL FACILITY (LCF) STUDY
Component Requirements For The LCF

Computer Sciences Corporation

ROME AIR DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
GRIFFISS AIR FORCE BASE, NEW YORK 13441

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This report has been reviewed and is approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This effort was undertaken to identify the necessary facilities, operating procedures, personnel, and software tools to effectively control the proliferation of Higher Order Languages for computer programming. This control would allow the Air Force (and all of DOD) to standardize on the use of a few well controlled programming languages. This in turn would promote the use of Higher Order Languages over Machine Oriented Languages with the added advantage of smaller development and maintenance costs for software, reduced

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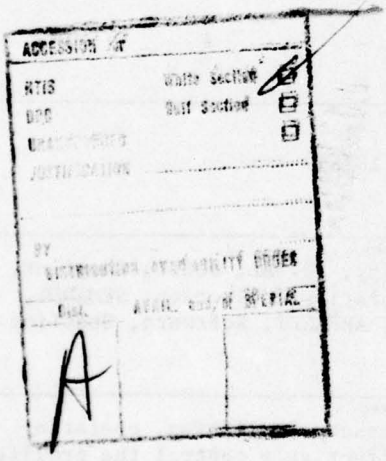
training costs for programmers, and increased transferability of both software and programmers.



EVALUATION

1. This effort, entitled "Language Control Facility (LCF) Study", was undertaken to investigate the tools, procedures, personnel, and facilities that would be needed to effectively control and standardize a high order language used for computer programming.

2. In the past, standardization of such programming languages usually ended with the production of a language specification. From that point on, implementations of the language (in the form of compilers) produced many "dialects" or variations. The occurrence of an implementation which came even close to the specification was rare, and the occurrence of two identical implementations was nonexistant. The variations in the quality and maintenance support of the compilers resulting from an implementation were probably even more pronounced, and the Air Force buyer of a compiler was usually not guaranteed any minimum performance. A final problem which often occurred was the uncontrolled ad hoc inclusion of new features because the language became out of date with requirements and/or did not take advantage of new hardware.

3. In order to solve the above problems, RADC undertook the development of several tools and techniques which provided the Air Force with a solution to or a good measure of control over the various problem areas of programming languages. However, most of the tools or techniques attacked primarily a single problem area or were not interfaced with one another, and it became obvious that the most benefit could be obtained by the use of all of the tools and techniques in conjunction with one another.

4. This effort, which was performed under TPO 11, "Software Sciences Technology," evaluated those tools and techniques with an eye towards uniting and interfacing them to perform the various tasks necessary to control one or more programming languages in the most efficient manner possible. At the time of the release of this report, many of the suggestions for modification of the existing tools were already underway.

5. With regard to the implementation of the actual facility itself, the Air Force has already initiated plans to implement a Language Control Facility along the guidelines proposed by this report before actual completion of the study. The prototype facility will operate for a two year trial period and will be responsible for the dialects of JOVIAL programming language called J3 and J73.

6. The concept of high order language control has now been adopted by the Department of Defense, and will be here on one scale or another from now on.

Samuel A. DiNitto, Jr.
Project Engineer

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

EXECUTIVE SUMMARY

There exists within the computer industry a multitude of Higher-Order Languages (HOLs) developed to satisfy the requirements of a growing number of applications. The U.S. Air Force, as an important member of the industry, has funded and continues to fund the development of HOLs. However, lack of guidelines for a standardized approach has resulted in the development of HOLs that only meet the requirements of a single user, or at best, a minimum number of users.

Because of the costliness of developing compilers and compiler languages for specific users, the Rome Air Development Center (RADC) has conceived the idea of a central Language Control Facility (LCF) to deal with all the elements of the HOLs. The goal of such a facility is to have compilers for the HOL readily available for any authorized user and to keep the HOL and its compilers up-to-date with respect to changing Air Force requirements.

In addition to the compiler itself, a significant amount of software would also be provided by the LCF to further support the HOL and encourage reliance upon and use of the LCF. This additional software is used to:

- Automate compiler development through use of prototype modules and compiler generation tools
- Validate compiler conformance to the HOL standard and analyze its reliability
- Monitor language usage to assist continual language growth
- Provide both compile- and run-time statistics to users for analyzing software costs and tuning systems
- Perform automatic program verification
- Support program checkout by performing HOL-level data generation, symbolic data reduction, and system scaffolding/modeling tools

This HOL-related software serves several purposes, primary of which is the reduction of total software life cycle costs by HOL usage and standardization. This alone cuts costs by increasing production, reducing programmer training (and retraining) requirements, eliminating redundant compiler development costs and enhancing software portability. The software also provides a very persuasive benefit for utilizing the LCF support and resisting application-dependent language extensions and the resulting version proliferation. Concentration of this software development and maintenance under the LCF permits spreading the costs of this support software to each user rather than burdening each with more cost for historically less capability.

This two volume report presents the results of a study performed for RADC by Computer Sciences Corporation (CSC) to analyze the major components of an LCF and to make recommendations for the implementation of single and multiple HOLs. In analyzing the usefulness and cost-effectiveness of an LCF, the following components that would make up the facility were examined in detail:

- Network and data communications between the LCF and the HOL users
- Hardware and computer systems required to host the LCF
- Formal operating rules and procedures between the LCF and HOL users
- Personnel staffing at the LCF
- Design of the physical facility
- HOL software tools

The first five components are discussed in Volume 1, and the software tools required to implement, control, and maintain the HOL are discussed in Volume 2. Costs for both developing and maintaining the LCF are included in Volume 1.

NETWORK AND DATA COMMUNICATIONS BETWEEN THE LCF AND HOL USERS

The initial task of the study group was to determine the communications requirements between the LCF and the HOL users and to evaluate current available communication networks for applicability in meeting these requirements. Four potential LCF communications configurations were defined and a user response time model was developed for evaluation purposes. Since the problem response time for manual baseline configurations was more than twice that of the automated baseline configurations, an automated form of communications is recommended. However, based on the relative costs for the semi-automated telecommunications, semi-automated teleprocessors, and fully automated configurations, as contrasted with the relative effectiveness, the semi-automated teleprocessing system is recommended.

Several existing computer communications networks then were investigated to select the optimum network for LCF implementation. Based on availability and several LCF specific performance requirements, the ARPANET was recommended for use by the LCF.

HARDWARE AND COMPUTER SYSTEMS REQUIRED TO HOST THE LCF

The hardware and computer systems capable of hosting the LCF were examined in detail. Comparative evaluations of the DECSYSTEM-10, UNIVAC 1108s and a combination of the H-6080 and H-6180 RADC systems were made. Based on computer availability, mass storage, costs, support software, network considerations, and communication requirements, the H-6080/H-6180 system offers a number of significant advantages over the other two candidate systems.

FORMAL OPERATING RULES AND PROCEDURES BETWEEN THE LCF AND HOL USERS

Control procedures are required for the following:

- Software error processing
- Software change processing
- Software release

During the development phase of the language and compilers, a Software Problem Report (SPR) is used to report errors. During the operational phase, users communicate their problems electronically to the LCF, where analysts determine whether the problem is an error, or requires a formal change. All formal changes are requested on a standard change request form and are submitted to a Configuration Control Board (CCB) for review and processing. System releases during development are relatively informal; however, during system operation by users, release procedures must be strictly controlled for content and user.

PERSONNEL STAFFING AT THE LCF

Personnel staffing needs for the LCF were examined in detail. The personnel qualifications for each proposed staff member, and the manpower sources of Air Force, civil service and government contractors, from which the personnel staff would be obtained, were evaluated. A staffing profile, headed by a Civil Service Computer Specialist as the LCF manager, together with a primary mix of Air Force and civil service personnel, is recommended.

DESIGN OF THE PHYSICAL FACILITY

The LCF design, based on the use of computer terminals rather than a total computer system, does not require any special considerations outside of the expected air-conditioning, power maintenance and consumable requirements. Parametric cost elements were developed and total costs for the facility were estimated.

The basic development costs of the LCF for controlling a single HOL are estimated at 169 to 275 man-months plus a fixed fee per anticipated user. The addition of a second HOL would add 122 to 218 man-months to the development effort. Monthly operation costs for a single HOL are approximately $14,000 per month with a monthly maintenance cost of 4 to 5 man-months. Addition of a second HOL would add $3,000 to the monthly operation and another 4 to 5 man-months to the monthly maintenance cost.

HOL SOFTWARE TOOLS

Volume 2 of the report deals with the software components required to support the LCF. In recent years, RADC has funded several programs that involved language support software tools. As part of the LCF study, CSC examined these tools to meet two requirements: (1) to analyze existing tools developed under RADC's sponsorship and (2) to make recommendations for incorporating these tools into an LCF. The following software tools were analyzed in detail:

- JOVIAL Compiler Implementation Tool (JOCIT)
- JOVIAL Language Management Tool (JLMT)
- JOVIAL Compiler Validation System (JCVS)
- JOVIAL Automated Verification System (JAVS)
- SEMANOL

JOCIT, which is aimed at providing low cost and efficient JOVIAL compilers for the J-3 language, was evaluated to be a competent and serviceable J-3 compiler tool for the recommended LCF computer configuration.

Although JLMT succeeds in identifying useful categories of statistics to be gathered, it does not define the functional specifications for a viable system. However, a language measurement tool would satisfy a real need in the LCF. In the section on proposed tools for the LCF, the omissions identified within JLMT are addressed and corrections are suggested.

The JOVIAL Compiler Validation System (JCVS) which has been implemented for both the J-3 and J73 Level I languages provides a useful base from which to develop validators for other HOLs. With the enhancements identified, JCVS could provide an even greater basis for compiler validation in an LCF.

The JOVIAL Automated Verification System (JAVS), implemented for J-3 users as a companion to the JOCIT Compiler under the HIS-6000 series, was evaluated to be a useful companion to the J-3 compiler. The JAVS principles and functional design also may be applied to other HOLs.

SEMANOL is a programming tool that allows description of both the syntax and the semantics of an HOL as a machine-verifiable language specification. Within the context of an LCF designed to support existing languages, SEMANOL was judged to be largely peripheral to the central tool requirement.

The LCF study was designed to be comprehensive in nature. Thus, the control of a language including the required control facility is described in Volume 1. A significant amount of user benefits, in terms of software support tools other than the compilers themselves, is described in Volume 2. Therefore, the reader's interest in either the control or support aspects of an LCF should be used to dictate volume preference.

SECTION 1 - INTRODUCTION

This volume, Volume 1, provides a detailed evaluation of all the LCF components (including a discussion of multiple HOLs from a single LCF) except software; Volume 2 provides a detailed evaluation of the software tools required to implement, control, and maintain the HOL. The remainder of this volume is organized as described in the following paragraphs.

Section 2 addresses the data communications requirements for the LCF. Four potential LCF communications configurations are defined and a response time model is developed. Using the model, computer simulations are performed and an optimum communications configuration is recommended.

The hardware and computer systems required to host the LCF are addressed in Section 3. This consists of comparative evaluations of three large-scale time-sharing computer systems: the DECSYSTEM-10, the UNIVAC 1108s (CSC's INFONET System), and a combination of the H-6080 and H-6180 RADC systems.

The operating rules and procedures required for the LCF are defined in Section 4. This includes detailed procedures for language acceptance testing, problem reporting, change proposals, and change control and implementation.

The personnel staffing requirements, as well as design and cost of the physical facility, are addressed in Section 5. An LCF organization structure and the job duties and personnel qualifications for each proposed staff position are defined, along with the recommended manpower sources for each position. The facility design for the LCF addresses: the equipment definition; facility floorspace and layout; consumables; maintenance; and air-conditioning and electrical power requirements. Finally, parametric cost elements are developed and total costs for the facility are estimated.

In Section 6, two approaches to controlling multiple HOLs are discussed. These approaches are: (1) controlling multiple HOLs from a single LCF and (2) from multiple LCFs. Both approaches are evaluated and the considerations of added staffing, facilities, and equipment are discussed.

SECTION 2 - COMMUNICATIONS AND NETWORK REQUIREMENTS

This section addresses two separate but closely related topics: the communications requirements for the LCF, and the network applicability to the LCF requirements. The discussion of the requirements for the LCF includes the definition of alternative communications configurations, and the formulation and exercising of an evaluation model to determine an optimum configuration. The network investigation included a survey of several existing telecommunications networks.

2.1 COMMUNICATIONS REQUIREMENTS

The approach taken to develop the LCF communications requirements consisted of several steps. First, the functional objectives for the communications system were developed. Then, alternative communications configurations were synthesized. Next, the operations and procedures required for each of the functional objectives were determined. Following this, an evaluation model was formulated, and performance parameters were estimated for each of the alternative configurations. Using the input parameters, the evaluation model was then exercised in a simulation to determine the expected performance of the four alternative configurations. Finally, the results of the simulation exercise were evaluated and an optimum communications system configuration was recommended.

2.1.1 COMMUNICATION SYSTEM FUNCTIONAL OBJECTIVES

Based on the LCF system requirements and objectives, the major functions of the communication system are to provide for:

- User problem definition
- Maintenance of HOLs and tools
- Evaluation of language utilization
- Determination of nonstandard compiler versions

2.1.1.1 User Problem Definition

There are five items to be considered in defining the user problem. The first is to identify any language deficiency in generating object code for a particular subset of source code. Next is to identify any problem in generating object code that meets the design/performance objective of a subset of source code. The third is to identify any language deficiency in addressing a particular functional design or performance objective without the need for use of machine level (assembly) code. The fourth is to identify any problem in interfacing subsets of code written in other languages for specific purposes (such as higher efficiency or to take advantage of hardware-specific features), with code elements written in the HOL. The final item is to identify problems in understanding a particular HOL feature and its application.

2.1.1.2 Maintenance of HOLs and Tools

Similarly, there are five items in this area. The first is design and implementation of HOL modifications. Next is dissemination of HOL modifications to the users. The third is the implementation and integration of the HOL modifications into the user system. The fourth is to verify that proper implementation and integration were performed. The final item is dissemination of information describing the HOL modifications to the users. All five items apply to both maintenance of the HOLs, and the HOL support tools.

2.1.1.3 Evaluation of Language Utilization

There are three points for consideration here. First, the language utilization data must be collected by the language analyzer operating in the user's compiler. Then, the collected data must be transmitted to the LCF. Finally, the data must be accumulated, analyzed, and interpreted at the LCF.

2.1.1.4 Determination of Nonstandard Compiler Versions

Six points are considered here. First, test codes must be generated. Then, the test codes must be transmitted to the user. Next, the user's HOL computer must

be accessed and the test code compiled. Then, the results of the compilation must be transmitted back to the LCF. Finally, the data must be evaluated at the LCF and a determination must be made of the deviations in the user's version of the compiler.

Later in this section, the detailed objectives identified above in each of the four areas are treated in one-to-one correspondence to the operations and procedures required to achieve them.

2.1.2 ALTERNATIVE CONFIGURATIONS

In this study, the following alternative communication systems were hypothesized for analysis:

- Manual baseline system
- Semi-automated telecommunications system
- Semi-automated teleprocessing system
- Automated telecommunications and teleprocessing system

2.1.2.1 Manual Baseline System

The manual baseline system presupposes no telecommunication links between the LCF and users' facilities other than ordinary telephone service. LCF user interfaces are accomplished by basically manual methods. Formal data, documentation, and other material exchanges are accomplished by mail (or courier). To the extent possible, documents and materials are in machine-generated and machine-readable formats.

2.1.2.2 Semi-Automated Telecommunication System

The semi-automated telecommunication system configuration is local terminal to remote terminal and assumes ordinary telephone service as well as telecommunication links between the LCF and user facilities, but not between LCF computers and user computers. Telecommunication facilities include terminal devices and line interface equipment. Terminal devices capable of accepting or producing machine-readable inputs such as cards, paper tape, or magnetic tape have been assumed to exist.

Intercommunication is accomplished by a combination of manual procedures and terminal-to-terminal data transmission. Formal document and material transmission using terminal devices is the basic means for information and data exchange between the LCF and HOL users. Where possible, documents and material transmission are effected in machine-generated and readable formats.

2.1.2.3 Semi-Automated Teleprocessing System

The third configuration, semi-automated teleprocessing, is local terminal to remote computer and assumes that ordinary telephone service as well as telecommunications links exist between the LCF and user facilities, but not directly between the LCF and user computers. The telecommunications facilities include terminal devices, line interface equipment, and computer interface equipment. Terminal devices in LCF and/or user facilities provide remote interface to user and/or LCF computers with teleprocessing capabilities.

LCF user interfaces are accomplished by a combination of manual procedures and automated data transmission such as computer to terminal, terminal to computer, and terminal to computer to terminal. Formal data transmission via terminal devices and terminal-computer interfaces is employed for information exchange between LCF and HOL users. To the extent possible, data transmission from the transmitting facility is accomplished by direct computer entry processing and machine-generated outputs at the receiving facility.

2.1.2.4 Automated Telecommunications and Teleprocessing System

Finally, the fourth alternative - an automated telecommunications and teleprocessing system - assumes ordinary telephone service as well as telecommunications links between the LCF and user computer systems. Telecommunications facilities include terminal devices, line interface equipment, and computer interface equipment. Terminal devices in the LCF and/or user facilities are capable of interface with their own computers and remote interface to the user and LCF

computers. Additionally, LCF user interfaces are accomplished by a combination of manual and semi-automated data entry procedures and automated data transmission (i.e., terminal to computer, computer to computer, and computer to terminal). Formal data transmission via terminal-computer and computer-computer interfaces is employed for information exchange and interaction between LCF and HOL users. To the extent possible, data transmission and direct interaction between the LCF and user computers is employed, resulting in directly usable machine-generated outputs at the LCF and user facilities.

2.1.3 SYSTEM OPERATIONS AND PROCEDURES

While conducting this study, detailed operations and procedures, as applicable for each functional objective, were determined for each of the four communication system configurations. To ensure completeness, the form shown in Figure 2-1, Communications Operations and Procedures Form, was used. Completed forms reflecting operations and procedures for each system objective as implemented in each of the alternative communication system configurations are contained in Appendix A - Communications Operations and Procedures.

2.1.4 ALTERNATIVE CONFIGURATIONS EVALUATION MODEL

This subsection reports the results of quantitative trade-offs of the alternative communication system configurations. An evaluation functional model of the LCF-user communications functions was developed; this model is described and the input parameters characterizing performance of the various manual and automated links in the four configurations are determined (or estimated). Using the input parameters, the evaluation model is exercised in a simulation to determine the expected performance of the configurations.

2.1.5 FUNCTIONAL MODEL

Based on the description of the communication system configurations and the operational procedures outlined in this section and described in Appendix A, a generalized functional model was developed. The model was used during the

User Problem Definition	System Operation & Procedures
(A) Identification of language deficiency in generating efficient object code for a particular subset of source code.	
(B) Identification of problem in generating object code which meets design/ performance objective of a subset of source code.	
(C) Identification of language deficiency in being able to effectively/efficiently address a particular function design/ performance objective without the need for machine level (assembly) coding for source code for the function.	
(D) Identification of problem of interfacing subsets of code written in other languages (assembly or other HOL) for specific purposes (i.e., higher, efficiency, take advantage of hardware specific features) with other code elements written in HOL.	
(E) Identification of problem in understanding particular HOL feature and its application.	

Figure 2-1. Communications Operations and Procedures Form (1 of 4)

Maintenance of HOLS and Tools	System Operation & Procedures
(A) Design and implementation of HOL/ Tools modifications (e.g., corrections, updates, extensions).	
(B) Dissemination of HOL/Tools modification to users.	
(C) Implementation/integration of HOL/ Tools modifications in user systems.	
(D) Verification of proper implementation/ integration of HOL/tools modifications in user systems.	
(E) Dissemination of information (e.g., notices, user guidelines) on HOL/ tools modification.	

Figure 2-1. Communications Operations and Procedures Form (2 of 4)

Evaluation of Language Utilization	System Operation & Procedures
(A) Collection of user language by language analyzer on user system.	
(B) Transmission of collected data from user to LCF.	
(C) LCF accumulation, processing, and interpretation of language usage data from various users.	

Figure 2-1. Communications Operations and Procedures Form (3 of 4)

Determination of Non-Standard Compiler Versions	System Operation & Procedures
(A) Generation and transmission of compiler test code(s).	
(B) Access to user HOL compiler.	
(C) Compilation of test code(s) by user compiler version.	
(D) Transmission of compilation(s) by user compiler to LCF.	
(E) LCF accumulation, evaluation, and determination of user compiler version deviation from standard.	

Figure 2-1. Communications Operations and Procedures Forms (4 of 4)

course of the study for estimating system response time (turnaround) time. Figure 2-2 depicts this generalized functional model. In this figure, rectangles represent events (stimulus/response pairs) while connecting lines represent functional arguments that may, depending on the alternative configuration under consideration, be implemented in different ways.

Table 2-1 summarizes the differences in implementation of the four configurations. Table 2-2 details the way in which each functional argument is implemented in each of the four configurations under consideration. The functional model developed may be used to simulate system response times using Monte Carlo techniques by means of the SOLVNET program, a general purpose program applicable to many network flow problems. In the LCF application, the times required to execute any of the system functional arguments shown in Figure 2-2 or Table 2-2 comprise independent performance parameter inputs. It was assumed that each of the alternative functional arguments is statistically independent.

The SOLVNET program was operated on performance parameter inputs (shown in Table 2-3) under the assumption that the function execution times are random with triangular probability density functions. The minimum time estimate is the execution time that is considered the shortest possible (probability-of-execution in less than the minimum time equals zero). Likewise, the maximum time estimate is considered to be the longest possible (probability-of-execution in longer than the maximum time equals zero). The nominal execution time corresponds to the mode of the triangular probability density function. Accordingly, the probability density at the nominal execution time estimate is given by twice the reciprocal of the difference between the maximum and minimum estimates.

The SOLVNET program accepts the execution time estimates for the functional arguments, together with network topology and modal logic operators, and by Monte Carlo techniques, determines the mean, standard deviation, and mode of the distribution of system response time.

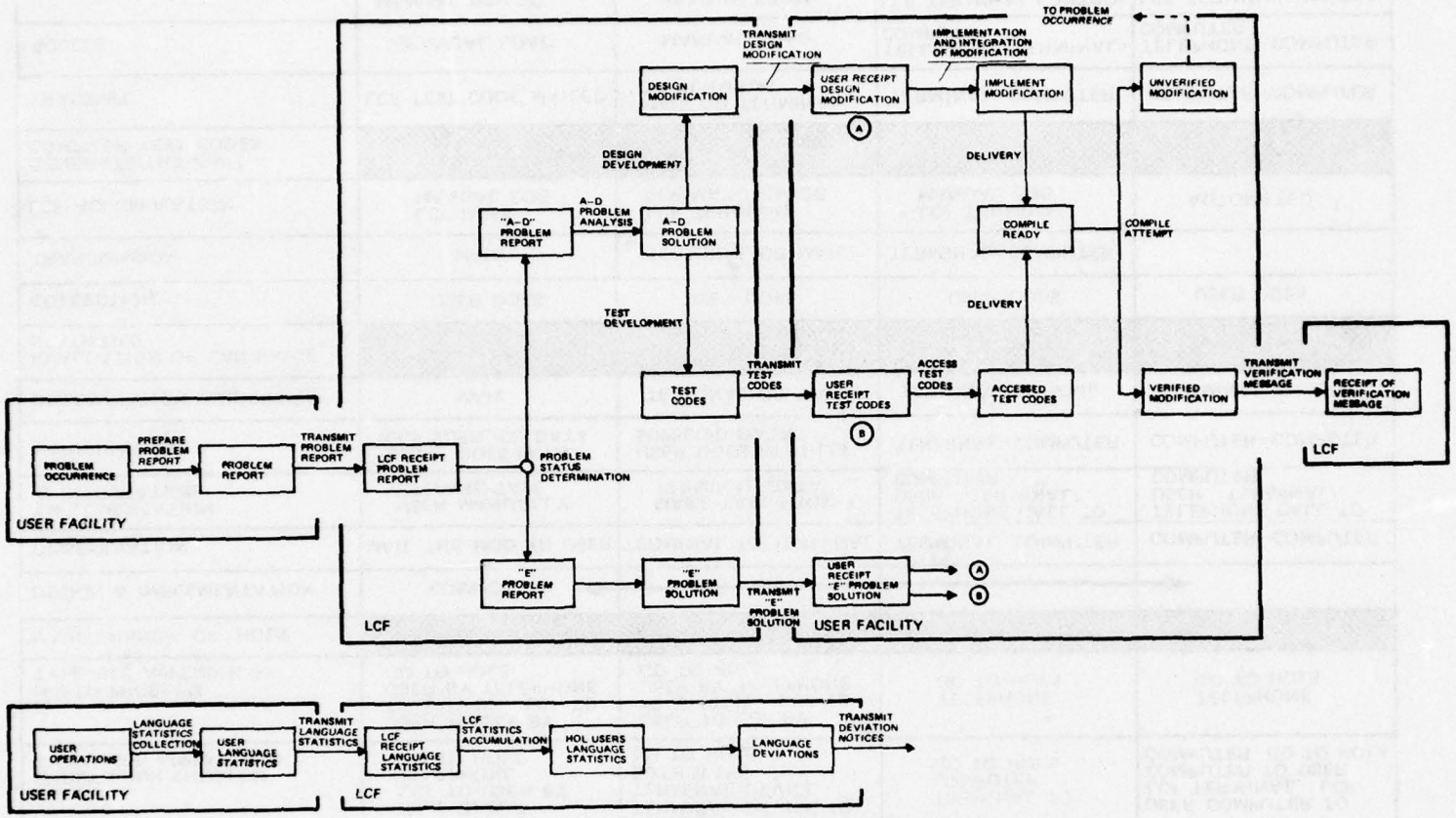


Figure 2-2. LCF-Users' Communication Functional Model

Table 2-1. Communication System Configurations

	MANUAL	S.A. TELECOMMUNICATIONS	S.A. TELEPROCESSING	AUTOMATED
USER PROBLEM DEFINITION				
A,B,C,D (FIRST FOUR PROBLEM TYPES–SEE APPENDIX A)	MAIL IN PDR LCF TO USER BY TELEPHONE GO TO HOLS	TERMINAL DEVICE TO TERMINAL DEVICE BOTH WAYS GO TO HOLS	TERMINAL TO COMPUTER GO TO HOLS	USER COMPUTER TO LCF TERMINAL. LCF COMPUTER TO USER COMPUTER. GO TO HOLS
E, (FIFTH PROBLEM TYPE–SEE APPENDIX A)	USER TO LCF BY TELEPHONE. LCF TO USER BY TELEPHONE GO TO HOLS	USER TO LCF BY TELEPHONE. LCF TO USER BY TELEPHONE GO TO HOLS	TELEPHONE GO TO HOLS	TELEPHONE GO TO HOLS
MAINTENANCE OF HOLS				
DESIGN & IMPLEMENTATION	COMMON ◄	———	———	——— ►
DISSEMINATION	MAIL THE MOD TO USER	TERMINAL TO TERMINAL	TERMINAL–COMPUTER	COMPUTER–COMPUTER
IMPLEMENTATION & INTEGRATION	USER MANUALLY PREPARE TAPE	MAKE TAPE FROM TERMINAL DATA	TELEPHONE CALL TO USER. TERMINAL/ COMPUTER	TELEPHONE CALL TO USER. TERMINAL/ COMPUTER
VERIFICATION	USERS DOES WITH LCF SUPPLIED DATA	USER DOES WITH LCF SUPPLIED DATA	TERMINAL–COMPUTER	COMPUTER–COMPUTER
DISSEMINATION GUIDELINES	MAIL	TERMINAL OR MAIL	TERMINAL OR MAIL	TERMINAL OR MAIL
EVALUATION OF LANGUAGE STATISTICS				
COLLECTION	USER DOES	USER DOES	USER DOES	USER DOES
TRANSMISSION	MAIL	TERMINAL OR MAIL	TERMINAL–COMPUTER	
LCF ACCUMULATION	LCF DOES MANUAL LOG	LCF TERMINAL LCF MANUAL LOG	LCF TERMINAL MANUAL LOG	AUTOMATED
GENERATE/TRANSMIT COMPILER TEST CODES				
TRANSMIT	LCF TEST CODE MAILED	MAIL OR TERMINAL TO TERMINAL	TERMINAL–COMPUTER	COMPUTER–COMPUTER
ACCESS	MANUAL LOAD	MANUAL LOAD	TELEPHONE, TERMINAL–COMPUTER	TELEPHONE, COMPUTER–COMPUTER
COMPILE	MANUAL OPN TO MACHINE READABLE	READ IN FROM TERMINAL	LCF TERMINAL CONTROL OF USERS COMPUTER	LCF TERMINAL CONTROL OF USER COMPUTER
TRANSMIT	MAIL	MAIL OR TERMINAL TO TERMINAL	TERMINAL–COMPUTER	COMPUTER–COMPUTER
ACCUMULATE	MAIL DEVIATIONS	MAIL DEVIATIONS	TERMINAL–COMPUTER	COMPUTER–TERMINAL

Table 2-2. Specific Functional Implementations (1 of 3)

Communication Configuration / System Functional Argument	Manual Baseline System	Semi-automated Telecommunication System	Semi-automated Teleprocessing System	Automated Telecommunication/ Teleprocessing System
Prepare problem report (A-D)	User manual operation	User manual operation	User manual operation	User manual operation
Prepare problem report (E)	User manual operation	User manual operation	User manual operation	User manual operation
Transmit problem report (A-D)	User mail to LCF	User terminal to LCF terminal	User terminal to LCF computer	User computer to LCF terminal
Transmit problem report (E)	User phone to LCF	User phone to LCF	User phone to LCF	User phone to LCF
Problem status determin. (A-D)	LCF manual operation	LCF manual operation	LCF manual operation	LCF manual operation
Problem status determin. (E)	LCF manual operation	LCF manual operation	LCF manual operation	LCF manual operation
A-D problem analysis	LCF manual operation	LCF manual operation	LCF manual operation	LCF manual operation
Design development	Aggregated in "A-D Problem Analysis" above			
Test development	Aggregated in "A-D Problem Analysis" above			

Table 2-2. Specific Functional Implementations (2 of 3)

Communication Configuration / System Functional Argument	Manual Baseline System	Semi-automated Telecommunication System	Semi-automated Teleprocessing System	Automated Telecommunication/ Teleprocessing System
Transmit design mod.	LCF mail to user	LCF terminal to user terminal	LCF phone user, then terminal-to-computer	LCF phone user, then computer-to-computer
Implement & integ. of mod.	User manual operation	User manual operation	LCF phone user, then terminal-computer	LCF phone user, then computer-computer
Delivery (mod)	Aggregated in "Imp. & Int." above			
Compile attempt	User computer operation	User computer operation	LCF terminal control of user computer	LCF computer control of user computer
To problem occurrence	User manual operation	User manual operation	User computer to LCF terminal	User computer to LCF computer
Transmit verification message	User mail to LCF	User terminal to LCF terminal	User computer to LCF terminal	User computer to LCF computer
Transmit test codes	LCF mail to user	LCF terminal to user terminal	LCF phone user, then terminal-to-computer	LCF phone user, then computer-to-computer

Table 2-2. Specific Functional Implementations (3 of 3)

Communication Configuration / System Functional Argument	Manual Baseline System	Semi-automated Telecommunication System	Semi-automated Teleprocessing System	Automated Telecommunication/ Teleprocessing System
Access test codes	User manual operation	User manual operation	User manual operation	User manual operation
Delivery (test)	Aggregated in "Access Test Codes" above			
"E" problem analysis	LCF manual operation	LCF manual operation	LCF manual operation	LCF manual operation
Transmit "E" problem solution	LCF phone to user	LCF phone to user	LCF phone to user	LCF phone to user
Language statistics collection	User computer	User computer	User computer	User computer
Transmit language statistics	User mail to LCF	User terminal to LCF terminal	User terminal to LCF computer	User computer to LCF computer
LCF statistics accumulation	LCF manual operation	LCF manual operation	LCF manual operation	LCF manual operation
Statistics analysis	LCF computer	LCF computer	LCF computer	LCF computer
Transmit deviation notices	LCF mail to user	LCF terminal-to user terminal	LCF terminal-to-user computer	LCF computer-to-user computer

Table 2-3. Functional Argument Execution Times Estimates (1 of 3)

Communication Configuration / System Functional Argument	Manual Baseline System	Semi-automated Telecommunication System	Semi-automated Teleprocessing System	Automated Telecommunication/ Teleprocessing System
Compile attempt	5.0 min* 7.0 min 20.0 min	5.0 min 7.0 min 20.0 min	5.0 min 7.0 min 20.0 min	5.0 min 7.0 min 20.0 min
To problem occurrence	5.0 min 30.0 min 60.0 min	5.0 min 30.0 min 60.0 min	5.0 min 7.0 min 10.0 min	5.0 min 7.0 min 10.0 min
Transmit verification message	8.0 hr 16.0 hr 32.0 hr	3.0 min 7.0 min 15.0 min	3.0 min 7.0 min 15.0 min	0.5 min 1.5 min 3.0 min
Transmit test codes	8.0 hr 16.0 hr 32.0 hr	15.0 min 30.0 min 60.0 min	10.0 min 13.0 min 15.0 min	3.0 min 4.0 min 6.0 min
Access test codes	0.5 hr 1.0 hr 1.5 hr	0.5 hr 1.0 hr 1.5 hr	5.0 min 15.0 min 30.0 min	5.0 min 7.0 min 10.0 min
Delivery (test)	Aggregated above			
A-D problem analysis	4.0 hr 8.0 hr 40.0 hr	4.0 hr 8.0 hr 40.0 hr	4.0 hr 8.0 hr 40.0 hr	4.0 hr 8.0 hr 40.0 hr
Design development	Aggregated above			
Test development	Aggregated above			

*Time estimates listed are minimum, nominal and maximum.

Table 2-3. Functional Argument Execution Times Estimates (2 of 3)

Communication Configuration / System Functional Argument	Manual Baseline System	Semi-automated Telecommunication System	Semi-automated Teleprocessing System	Automated Telecommunication/ Teleprocessing System
Transmit design mod.	8.0 hr* 16.0 hr 32.0 hr	15.0 min 30.0 min 60.0 min	10.0 min 13.0 min 15.0 min	3.0 min 4.0 min 6.0 min
Implement & integ. of mod.	0.5 hr 2.0 hr 4.0 hr	0.5 hr 2.0 hr 4.0 hr	0.5 hr 1.0 hr 1.5 hr	5.0 min 15.0 min 30.0 min
Delivery (mod.)	Aggregated above			
Prepare problem report (A-D)	1.0 hr 1.5 hr 2.0 hr	1.0 hr 1.5 hr 2.0 hr	1.0 hr 1.5 hr 2.0 hr	1.0 hr 1.5 hr 2.0 hr
Prepare problem report (E)	Aggregated above			
Transmit problem report (A-D)	8.0 hr 16.0 hr 32.0 hr	1.0 hr 1.5 hr 2.0 hr	10.0 min 30.0 min 40.0 min	0.5 min 1.5 min 3.0 min
Transmit problem report (E)	Aggregated above			
Problem status determin. (A-D)	1.0 hr* 4.0 hr 40.0 hr	1.0 hr 4.0 hr 40.0 hr	1.0 hr 4.0 hr 40.0 hr	1.0 hr 4.0 hr 40.0 hr
Problem status determin. (E)	Aggregated above			

*Time estimates listed are minimum, nominal and maximum.

Table 2-3. Functional Argument Execution Times Estimates (3 of 3)

Communication Configuration / System Functional Argument	Manual Baseline System	Semi-automated Telecommunication System	Semi-automated Teleprocessing System	Automated Telecommunication/ Teleprocessing System
(E) problem analysis		Aggregated above		
Transmit (E) problem solution		Aggregated above		
Language statistics generation	8.0 hr 32.0 hr 120.0 hr	8.0 hr 32.0 hr 120.0 hr	8.0 hr 32.0 hr 120.0 hr	8.0 hr 32.0 hr 120.0 hr
Transmit language statistics	8.0 hr 32.0 hr 96.0 hr	10.0 min 15.0 min 30.0 min	10.0 min 15.0 min 30.0 min	0.5 min 1.5 min 3.0 min
LCF statistics accumulation	20.0 min* 40.0 min 60.0 min	20.0 min 40.0 min 60.0 min	10.0 min 13.0 min 20.0 min	2.0 min 5.0 min 10.0 min
Statistics analysis	10.0 min 20.0 min 40.0 min	10.0 min 20.0 min 40.0 min	10.0 min 20.0 min 40.0 min	2.0 min 5.0 min 10.0 min
Transmit deviation notices	8.0 hr 16.0 hr 32.0 hr	20.0 min 40.0 min 60.0 min	10.0 min 13.0 min 20.0 min	0.5 min 2.5 min 3.0 min

*Time estimates listed are minimum, nominal and maximum.

2.1.5.1 Input Parameters

Input parameters for the functional model consist of estimates of execution times for the various functional arguments as implemented in the four configurations. These estimates (based on a consensus of experience) are shown in Table 2-3, Functional Argument Execution Times Estimates.

2.1.5.2 Quantitative Evaluation

The input parameter estimates were used in the SOLVNET model to simulate system response times for both the Problem Occurrence-Receipt of Verification Message throughput thread and the User Operations-Language Deviations Thread. These threads are called problems and statistics, respectively. The problem thread has two cases: A-D problems and E problems. E problems, to be handled by telephone, are expected to require only a few minutes to a few hours for reconciliation, so they were not simulated by SOLVNET. Table 2-4 summarizes the results of both the A-D problems thread and the statistics threads.

2.1.6 CONCLUSIONS AND RECOMMENDATIONS

Certain conclusions are evident in Table 2-4. First, a problem system response time for the manual baseline configuration is more than twice that of the automated configurations; that is, about nine days for manual as compared to about four days for the automated configurations. Likewise, language statistics response time for the manual configuration is more than twice those for automated configurations - seven days versus three days. Inasmuch as the standard deviations are approximately the same for every configuration, no distributions can be made on that basis.

Experience with similar information storage and retrieval systems suggests that the value (or utility) of information depends mainly on the type of application and timeliness. Generally, expected voluntary utilization can be expected to increase as response time decreases. Accordingly, nine days is too long a time to ensure adequate user participation to justify the system; hence, the manual baseline configuration is not recommended. Inasmuch as response times are approximately

Table 2-4. System Response Times

System Configuration	A-D Problem Thread		Statistics Thread	
	Mean (hrs)	Std. Dev. (hrs)	Mean (hrs)	Std. Dev. (hrs)
Manual Baseline	213	39	179	31
Semi-automated Telecommunication	91	36	67	20
Semi-automated Teleprocessing	89	40	64	20
Automated Telecommunication/ Teleprocessing	87	40	63	20

the same for all three automatic configurations, the choice of automation is not dictated by a response time rationale. Rather, based on the relative costs for the approximately equivalent semi-automated telecommunication and semi-automated teleprocessing systems, as contrasted with the substantially higher fully automated configuration costs, the semi-automated teleprocessing system is recommended.

2.2 NETWORK APPLICABILITY

In developing the performance requirements for computer communication networks, three general considerations apply. First, computer-to-computer or terminal-to-computer communications network requires a burst transmission rate several orders of magnitude higher than average rates. Statistics on teletypewriters, graphic consoles, and batch terminals show that the ratio of burst rate to average rate is approximately 100 to 1. This indicates that if a standard communications line is established for a computer conversation, the average utilization of that line will be only about 1 percent, and therefore the cost will be 10 to 100 times higher than the cost of moving the data bits.

The second consideration is that the connect time (time required to initially establish a communications link) must be short enough that the computer or computer users are not delayed unduly. An acceptable connect time for computers is less than one second as opposed to 20 or 30 seconds for voice communications.

The final general consideration is that the error rate for intercomputer traffic must be far lower than that required for voice communications, since there is usually little redundancy in the system. At the same time, the reliability or uptime of the data communications system must be high enough to ensure the resource availability to the remote user.

Few communication systems exist that possess the characteristics just described. One innovative and state-of-the-art communications system that does possess these characteristics is the ARPA Network (ARPANET), which is described later. Prior to the discussion of ARPANET, three other communications networks are

discussed for applicability to the LCF communications requirements: AUTOVON, AUTODIN, and a common carrier-based network.

2.2.1 AUTOVON

AUTOVON is essentially not applicable to the requirements of the LCF user communications interface. This conclusion is based on the procedural constraints on use of system facilities rather than on inability to meet the technical requirements.

AUTOVON is basically intended for voice rather than data communications or interoperation of data processing equipment. AUTOVON access is not available to Government contractors without special approval by DCA. Furthermore, without special approval by DCA, the constraints on use of AUTOVON for data operations include:

- Limit on circuit-holding (continuous interconnect) time on a single subscriber line of up to 15 minutes at any time during the working day; no limit after the working day (7 a.m. to 5 p.m. in each time zone)
- Total allowable holding time for all connections in a working day limited to one hour (e.g., four 15-minute periods)
- User must disconnect after one minute without data criteria
- User terminal equipment must have built-in features that automatically apply 15-minute holding time and one minute without data criteria to truncate connection

It is not likely that DCA would find the objectives of the LCF in keeping with the intended purposes of AUTOVON, or important enough to grant special exceptions to the above constraints.

2.2.2 AUTODIN

AUTODIN is applicable only to certain of the operations described in the three automated communications interface system definitions. These would be

operations or functions for which direct and continuous connection is not required and for which time delays in data transmission are not critical.

AUTODIN is basically a store-and-forward message-switching system. There is no guarantee of immediate connection between transmitter and receiver facilities for data transmission. Transmission during the same day is guaranteed, however. The usual maximum delay between data input and reception at designee is about two hours. Thus, AUTODIN might only be applicable to the semi-automated telecommunications LCF system.

Contractors can have access to the network. However, all communications line installations must be permanent. In addition, the LCF and user computers must be programmed, or terminals designed (or programmed) for the AUTODIN protocols. Thus, AUTODIN would be costly for use where the number of HOL users is large.

In general, AUTODIN does not appear to be a practical choice for communications interface between LCF and users, because of the above limitations.

2.2.3 COMMON CARRIER-BASED COMMUNICATIONS NETWORK

It would be possible to design and implement a communications network to meet the LCF requirements and/or desired capabilities based on use of common carrier network facilities. However, any automatic call-direct access capabilities would have to be implemented as interface equipment at LCF or user facilities. In addition, there would definitely be a need for specific engineering effort to design the total network, procure the interface equipment and terminals with any special features, and install the interface equipment.

Where there are likely to be a large number of users who may leave or enter the system at any time (e.g., contractor dropout when project is completed), engineering installation and removal of appropriate interface equipment would be difficult and costly to administer. Also, when classified software is being developed by a user, this network could not be employed for transmissions of any related data.

Because of these deficiencies, use of an existing DOD communications network should be considered before a common carrier-based communications network.

2.2.4 ARPANET

The ARPANET is applicable to all of the LCF communications requirements. This network creates a switched network out of full-period leased lines by inserting switching computers at appropriate nodes. The data transmitted between the computers is divided into fixed-length packets whose length is not in any way connected with the message control. A packet length is 1000 bits and the packets are treated as independent data blocks to be sent over whatever path happens to be free at the moment. At the destination, the packets are reassembled in the proper order and forwarded to the receiving computer.

The interface with the network is accomplished via an Intermediate Message Processor (IMP) for interfacing a computer, or a Terminal Interface Processor (TIP) for interfacing both computers and terminals. Each IMP or TIP has at least two connections to other IMPs or TIPs, and some have as many as three or four. A message from one computer to another is not necessarily all transmitted on the same lines. This is accomplished by the packet-switching concept mentioned above, and allows the network to use all of its communications lines more efficiently. (The technical and cost considerations of interfacing the LCF terminals with ARPANET are discussed in Section 3 of this volume.)

IMPs or TIPs are located throughout the nation, and terminals can be directly interfaced with a TIP by plug connection or by the use of modems. ARPANET host computers employ standard ARPANET protocols that are currently available for most large-scale timesharing computers. Often, the only software requiring modification is the user's executive software (to interface the standard ARPANET protocol package).

General performance of the ARPANET system is exemplified by its capability to deliver short messages anywhere in the country in 0.1 second and by permitting

throughput rates of up to 80 kilobits per second on long messages. Direct connection of up to 64 consoles and peripheral devices to a single TIP providing intercommunication with remote hosts (computers or terminals) at rates of up to 20 kilobits per second is also possible.

The single drawback found with this network is that it is not secure. However, this fact is not considered in itself to be a critical constraint, as problems involving classified code represent only a very small portion of all problems encountered with a HOL. Classified code, when encountered, can be handled by secure manual procedures.

The preceding discussion indicates that ARPANET is indeed applicable to the LCF communications requirements. CSC recommends this network for implementation of the LCF.

SECTION 3 - HARDWARE AND COMPUTER SYSTEMS

This section defines the characteristics of the hardware necessary to support the LCF mission, objectives, and software tools. LCF system requirements are identified, and selection of candidate host computer systems is discussed. Next, detailed evaluations are made of each candidate host against the LCF requirements. Lastly, the candidate hosts are evaluated comparatively, and feasible cost-effective hardware is recommended for LCF implementation.

3.1 STUDY APPROACH

The hardware surveyed in this study includes various types of terminal devices (teletypewriter, display, batch, and intelligent terminals) as well as three candidate host computer systems. The computer systems are:

- UNIVAC 1108s (CSC's INFONET System)
- DECSYSTEM-10
- Combination of Honeywell 6080 and 6180 systems (RADC Configuration)

In evaluating these systems, the following assumptions were made:

- Computer time on all of the host computers is equally available
- Sufficient mass storage for LCF permanent files is available in each system
- Costs for computer time on the host computers were considered subject to change and were therefore not compared; should implementation of an LCF be undertaken by RADC, these cost factors can be added to the computer system weighting matrix provided in this section

3.1.1 METHODOLOGY

The methodology used in performing this hardware study is depicted in Figure 3-1. The initial function of this study was to identify the system data processing

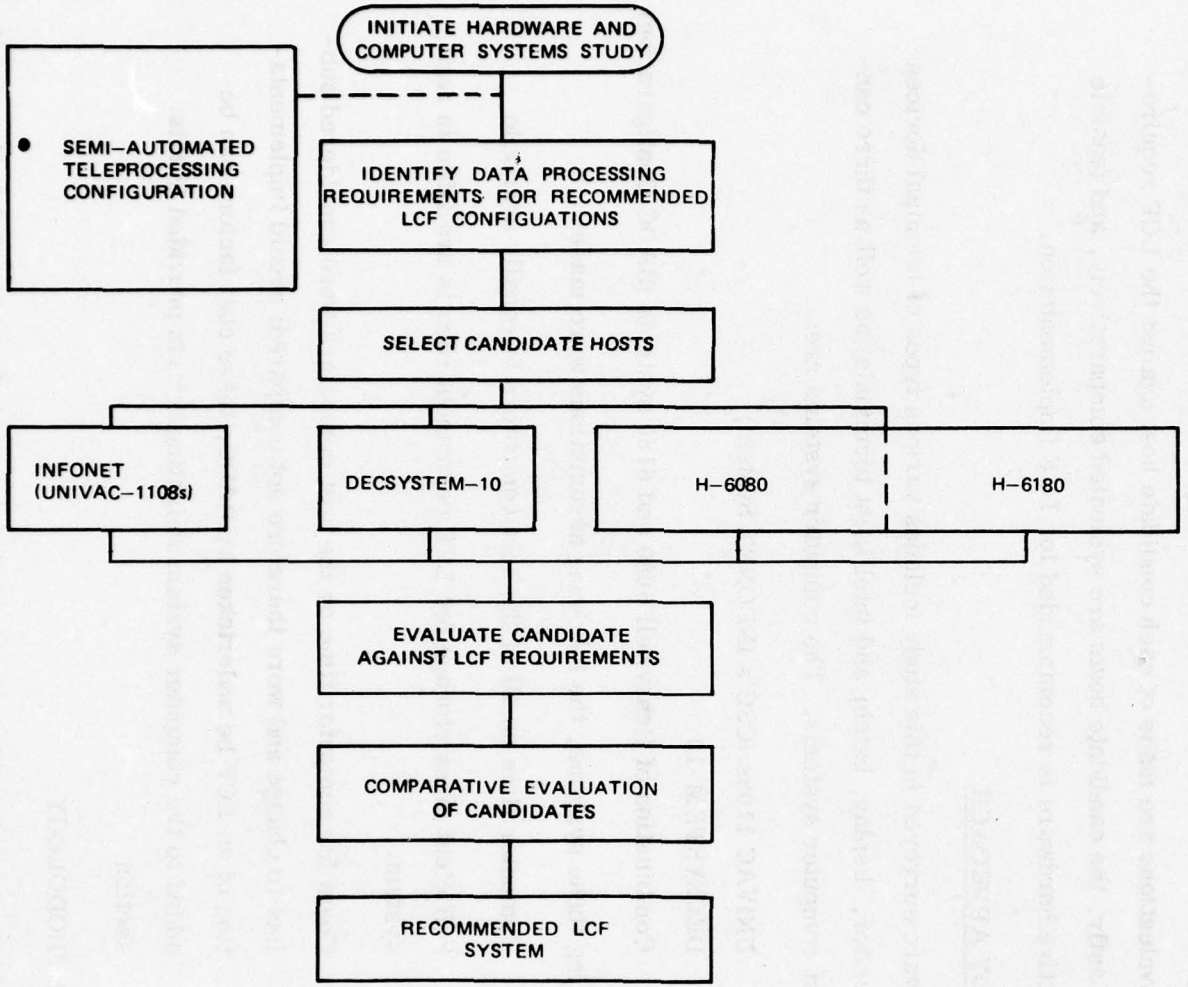


Figure 3-1. Hardware and Computer Systems Study Methodology

requirements for each of the LCF configurations recommended in Section 2. Based on the identified requirements, three candidate host computer systems were selected. Following this selection, each of the candidate systems was evaluated against the LCF requirements. Next, comparative evaluation of the three candidates was performed, and hardware recommendations for a cost-effective LCF system implementation were made.

3.1.2 LCF COMMUNICATIONS CONFIGURATIONS

Of the four communication configurations discussed in Section 2, the manual and fully automated were rejected as least desirable. Of the two semi-automated configurations remaining, the teleprocessing configuration was recommended. Accordingly, this configuration was examined to determine the system data processing requirements for it. An identification of these requirements follows.

3.1.3 LCF SYSTEM DATA PROCESSING REQUIREMENTS

The data processing requirements for the selected LCF configurations can be categorized as follows:

- Storage requirements
- Communications requirements
- Support software requirements
- Host computer operating environment

Cost evaluations, required to ensure the cost-effectiveness of the recommended LCF hardware and computer system, are provided in this section. These evaluations consist of cost estimates for the new hardware and new software associated with each of the three candidate host systems.

3.1.3.1 Storage Requirements

Storage requirements for LCF data files have two major aspects. The first involves the mass storage requirement for permanent LCF files. This requirement can be assumed to be satisfied by the extremely large storage hardware

resources of each of the candidate timesharing systems. The second aspect of LCF data storage is the user file protection required to provide security for LCF permanent data files.

3.1.3.2 Communications Requirements

Communications requirements also consist of two categories or types of requirements. The first is the hardware user interface. This will consist of data terminals that are plug-compatible with the hosts and/or the recommended communications network (ARPANET). The second type of communications requirement involves interconnection of the host with the ARPANET.

3.1.3.3 Support Software Requirements

Support software requirements for the LCF can be focused on three areas of software. The first of these is the user interface command language provided by the host computer operating system. The second is the file management capabilities of the operating system. And the third is the implementation of, or the feasibility of the implementation of, the LCF software tools on the host computer.

3.1.3.4 Host Computer Operating Environment

The operating environment required for LCF data processing includes both local and remote conversational terminal processing, local batch processing, and timesharing of CPU time.

3.1.4 LCF CANDIDATE SYSTEMS

Candidate selection was performed based upon the LCF system requirements identified above, plus the additional criteria of system availability and use of existing Air Force-owned computer hardware. Treating the LCF system requirements as quantitative criteria and the two additional criteria as qualitative, CSC selected three candidates. The candidates are: UNIVAC 1108s (CSC's INFONET System), DECSYSTEM-10, and a combination of the H-6080 and H-6180 systems.

Examination of these three candidates has shown that each meets, or can be feasibly modified to meet, the critical data processing requirements for an LCF system. However, the cost of implementing these systems was found to vary significantly.

3.2 DETAILED REQUIREMENTS

Each of the candidate systems was individually evaluated and judged against each of the LCF system requirements. The merits and demerits of each system are described in terms of the implementation of file protection, terminal devices, telecommunications interface, support software, operating environment, and new hardware and software costs.

3.2.1 STORAGE-FILE PROTECTION

3.2.1.1 INFONET 1108s

In the INFONET system, file protection is provided at three levels: system access, data access, and data protection. System access involves establishment of unique library and file identifiers by computer center personnel working with the users. Data access is provided by operating system attachment of the file identifier and file access attribute data (generated by the creating user and the system) to the physical file and library. Both private and shared usage are accommodated via the access attributes. Types of access provided include unrestricted, restricted (add, update new file, execute), and read only. The third level of file protection is data protection. This protection consists of hardware and software features that prevent direct addressing of the data on any storage medium, and requires that the data be indirectly addressed by file name. Data protection also is provided against loss caused by hardware malfunctions through parity checking, program checksumming, and file logging to provide backup.

3.2.1.2 DECSYSTEM-10

File protection in the DECSYSTEM-10 is similar to that implemented in the INFONET system, in that file attributes are declared by the creating user (and the system) and are attached to the user file by the operating system. The standard read or modify privileges are provided the author and multiple users by the file attributes. File addressing is by file name only. A significant positive feature of the DECSYSTEM-10 file protection mechanism, which is not conventional, is that of providing three classes of file protection to three different types of users: (1) author of file, (2) users with a common project number, and (3) all users.

3.2.1.3 H-6080 GCOS

File protection in the GCOS system is a function of the File Management Supervisor (FMS) software and Base Address Register (BAR) addressing in the slave processors. FMS is a hierarchical file (or catalog) data structure that dynamically assigns permanent files to storage devices, and protects file access. The protection mechanism consists of multiple levels of control, as follows. No user can address a cataloged permanent file except through FMS, and user validation name and password (attribute) procedures are dynamically created and implemented by FMS. Privileged shared access of files also is provided. Privileges include read only, read and write, purge, modify catalog, lock and unlock, and other specialized options. And by user option, all file access attempts (invalid as well as valid accesses) can be recorded for any permanent file. And finally, permanent files residing on shared storage devices are protected by a lock byte, to prevent erroneous updating that otherwise would be possible through multiple user accesses.

3.2.1.4 H-6180 MULTICS

File protection implementation in the MULTICS system represents the current state-of-the-art, and it is accomplished by file access control lists and by eight

levels of software and hardware privileged file access. Data and instruction connectivity in the "on-demand paged" address space (i.e., total main memory plus mass storage) of the MULTICS virtual memory and storage system is accomplished by segmentation. All information in the system is organized into hierarchical trees composed of segments. There are two types of segments: (1) directory segments and (2) nondirectory segments. Associated with each segment is an access control list that contains the access attributes for the segment. The access attributes are status, modify, append, and null (no access) for directory segments, and read, write, execute, and null for nondirectory segments.

In addition to the access control lists, there is another more precise file protection mechanism provided in the MULTICS system. This is ring protection. It consists of system and user structuring of all information (data and instructions) into eight concentric ring domains. The rings are numbered 0 through 7 with Ring 0 being the most privileged domain and Ring 7 the least privileged. Ring protection differs from conventional file protection mechanisms in that instead of the usual two levels of protection, there are eight. In this structure, intra-ring access and lower-to-higher ring access require only that proper access control list name inclusion be provided. However, higher-to-lower ring access also requires the use of a program gate that must be supplied by the owner of the lower ring segment. This mechanism offers the maximum flexibility to both system and user software by providing a large number of security levels to each - three levels to system software and five levels to user software.

A summary of the file protection features provided by each of the candidate systems is depicted in Table 3-1.

Table 3-1. Candidate System File Protection Features

Requirements / System	File Name Addressing	Shared Access Attributes	Multiple Classes of Users	Access Recording	Multiple Levels
UNIVAC 1108	X	X			
DECSYSTEM-10	X	X	X		
H-6080	X	X		X	
H-6180	X	X	X		X

3.2.2 TERMINAL DEVICES

Terminal devices fall into four categories of terminals: (1) teletypewriter, (2) display, (3) batch, and (4) minicomputer. In general, equipment costs increase in the same order in which the categories above are numbered (i.e., teletypewriter costs least; minicomputer costs most). Typical equipment cost ranges for each category are:

Device Category	Typical Cost
Teletypewriter	$1,500 to $7,500
Display	$5,000 to $22,500
Batch	$10,000 to $60,000
Minicomputer	$35,000 to $150,000

From these gross cost comparisons, it is easily seen that the teletypewriter terminal holds a distinct advantage in cost. In addition to cost, the other factors that must be considered in selecting terminal equipment are: reliability, editing and formatting capabilities, operating speeds, and input/output medium. With all of these factors considered, the terminal equipment was examined in terms of the terminal data entry/output requirements for the LCF.

ARPANET, with its powerful protocols for remote terminal processing and data file transfer, considerably reduces the problem of terminal selection. Using ARPANET and the TELENET, LINK, MAIL, and FILE TRANSFER protocols, the LCF (and users) terminals are required to perform only the following types of message communications:

- Execution control of remote programs
- Execution control of local programs
- Data entry for remote programs
- Print nominal volume message data
- Initiation of local data file transfer

Collectively, these communications messages do not constitute high volume input/output, as a number of them consist of conversational command and control messages only. Further, the criticality of these message communications can be considered low, because the functions of the LCF are not performed in real time.

Therefore, two conclusions follow:

- The need for a minicomputer to handle the communications control function is obviated by the scope and power of the ARPANET protocols
- The need or convenience of the better editing and formatting features provided in a display terminal is difficult to justify because of the relatively small number of message types, the off-line environment, and the additional costs

With these considerations, the choice of terminal types focuses on the batch or teletypewriter terminal.

To evaluate the advantage of the batch and teletypewriter terminals in this application, the detailed requirement must be examined. In the LCF application,

message data to be communicated between the LCF and the users appears to be of two distinct types. The first type is a set of conversational messages as shown below:

	Message Type	Originating With	Communicating With
1.	Local program execution control - for compiler validation and language statistics analysis	LCF Terminal	LCF Host
2.	Remote program execution control - for compiler validation	LCF Terminal	User Host
3.	Software problem reports	User Terminal	LCF Terminal
4.	Language compiler change proposal	User Terminal	LCF Terminal
5.	Remote data entry - for input of language statistics	User Terminal	LCF Host
6.	Language status queries	User Terminal	LCF Host

Considering the off-line environment of the LCF, a teletypewriter terminal offers adequate reliability, editing and formatting, operating speed, and I/O medium for these messages.

A second type of data that must be communicated between the LCF and the users consists of the following higher volume messages:

- Software problem report data package
- Compiler modifications
- Compiler test data
- Language status

Because of its larger volume, this message data indicates the need for an I/O medium other than a teletypewriter. The more desirable I/O media would be: card reader and magnetic tape for input; card punch, magnetic tape, and line printer for output.

Based on these requirements, the optimum terminal device is seen to incorporate features of both batch and teletypewriter terminals (i.e., interactive keyboard, card read/punch, magnetic tape, and line printing).

An obvious, although expensive, approach to providing these features is a full capability minicomputer. A second and significantly more economical approach is to use two terminals: a teletypewriter terminal for the conversational mode requirement; and a low-speed, low-volume, batch terminal for the higher-volume data communications. Unfortunately, neither of these approaches can be easily nor economically implemented using the ARPANET, which does not directly support batch terminals incorporating a synchronous device. (Two batch options were available in the past on ARPANET - (1) a remote job minihost option and (2) a magnetic tape option - but both options have been discontinued.)

Another consideration, however, is that the local host computer (e.g., H-6180) could be used to interface the LCF batch terminal with the ARPANET TIP, but this consideration, while providing batch processing at the LCF, does not in itself provide the user with a batch medium.

A third approach offers feasible and economical implementation of the required features for both the LCF and the user. This approach is a variation of the second approach in that it involves implementing a teletypewriter terminal for the conversational mode requirement, plus the use of the previously-mentioned ARPANET protocols implemented in a local host computer (i.e., H-6180 and the user host) for the higher volume data communications.

Considering the significant implementation cost differentials, the third approach is the approach which CSC recommends. It is further recommended that two teletypewriter terminals be used in the LCF: one terminal to communicate with the users through the MULTICS system and the ARPANET TIP, the other to communicate with the LCF software tools residing in the GCOS system.

The model of teletypewriter terminal recommended for the LCF (two terminals) and for the users (one terminal per user) is a GE TERMINET-300 (or equivalent). The characteristics of this teletypewriter terminal are shown in Table 3-2, and the rationale for its selection is based on the following features.

- Ease of use
- Hardware reliability and maintenance availability
- 30 cps printer speed
- 96 print/128 keyboard ASCII character set offered
- Unattended data entry via punched paper tape and computer polling
- Communications interface compatibility (RS 232C) with most large-scale timesharing systems and with the ARPANET TIP

3.2.3 TELECOMMUNICATIONS NETWORK INTERFACE

This requirement has been qualified further by the recommendation of the ARPANET in Section 2, since only the DECSYSTEM-10 and H-6180 are available on this network.

3.2.4 USER INTERFACE SUPPORT SOFTWARE

3.2.4.1 INFONET-1108s

The General Programming Subsystem (GPS) of the INFONET System provides a diverse set of command functions to the user. These functions can be grouped into eight major command groups:

- Session control and inquiry (interactive or batch)
- Program construction and control
- File and library management
- File editing

- Program checkout
- Batch management (and unit record output formatting)
- Control terminal management (declare terminal characteristics)
- Command programming (insert, qualify, and delete commands from the control stream)

Collectively, these commands provide a flexible user control interface to a large remote user community. They also are supported by a common diagnostic facility, which provides either abbreviated or detailed (at user option) error messages containing associated error severity-level indicators.

Table 3-2. Characteristics and Capabilities of the GE TERMINET-300

COMPATIBILITY	Teletype IBM 2740	Yes No
MODEL CONFIGURATION	KSR ASR	Yes Yes
FEATURES	Parity Checking Parity Generating Polling/Addressing Automatic Answer	Optional Standard Optional Optional
PRINTER	Rate (Char/Sec) Character Set	30 96 ASCII; others
KEYBOARD	Character Set	128 ASCII
TRANSMISSION	Mode Speed (bits/sec) Code Communications Interface Integral Modem Telephone Coupler	Half/Full Duplex 110/150/300 8-Level ASCII RS 232C or 20 ma DC Optional Optional
PRICING	Lease (1 year) Purchase	$105-$237 $3,170 to $6,610

3.2.4.2 DECSYSTEM-10

DECSYSTEM-10 provides some features not found in the INFONET system, in that its command language is designed to optimize service to both local and remote users. These features include:

- More extensive file manipulation commands (particularly for source files)
- Terminal-to-terminal communications
- Multiple job control commands
- Commands allowing terminal disconnect and subsequent job resumption at point of disconnect (functionally, a session termination snapshot/reload capability)

3.2.4.3 H-6080 GCOS

The common language of the GCOS system provides a diverse and flexible set of commands to a local user community, and through the application of a front-end communications processor, these commands also are available to remote users. The commands feature:

- Interactive terminal and batch job control
- Direct program access (from interactive terminal) to batch jobs
- Language translators, compilers, and assemblers
- File and catalog management
- Source and object file editing
- Program checkout and monitor commands
- Resources accounting

3.2.4.4 H-6180 MULTICS

The MULTICS command language consists of 18 command groups providing extensive directory and segment manipulation and editing, and output data formatting. Six of these command groups address the storage system: creating

and editing segments, segment manipulation, directory manipulation, access control, formatted output facilities, and address space control. (It should be noted that the virtual memory environment of the MULTICS system often tends to simplify and reduce the total job control language requirements imposed upon the user.) In addition to addressing the storage system, the MULTICS command language also provides complete and flexible user control of program generation, execution, and check-out; command entry; resources accounting; communications with the system; and communications between users.

3.2.5 FILE MANAGEMENT SUPPORT SOFTWARE

3.2.5.1 INFONET-1108s

In CSC's Teleprocessing System (CSTS) the file system is constructed of libraries composed of files. The system software resides in its own library and is of course protected from the user. A user library is created beginning with the creation of temporary files in the user session. At completion of creation of the files, the files can (by user option) be made permanent and be assigned to a user-specified storage medium (drum, disk packs, or magnetic tape) by CSTS. If no storage medium is specified, CSTS selects the medium. CSTS also performs and controls all allocation.

In mass storage allocation, the standard unit of allocation is a page, which consists of 512 words. CSTS offers two mass storage allocation techniques: standard and sheaf. The standard technique uses page and folio allocation (four sequential pages). The folio structure is used to minimize access time between sequential folio pages. Sheaf allocation is available only for extremely large disk files and is directly related to the physical characteristics of the storage device (i.e., minimizing disk arm positioning). In this file system, the user can specify his magnetic tape allocations by command.

All files created are addressable by file identifier and system and user-generated file attributes associated with the file. Privileged file protection is provided as

described above. Magnetic tape files can be structured in standard-length (512 word) physical records or user-specified nonstandard length records. Unit record device handling is always performed by CSTS I/O routines.

3.2.5.2 DECSYSTEM-10

The same file management capabilities provided in INFONET's CSTS are generally provided in the DECSYSTEM-10 operating system. Some differences are:

- The standard unit of storage allocation is a 128-word block or file
- Permanent files are relocated by the operating system to dedicated user storage areas (of disk storage)
- Different file access privileges can be granted to multiple (three) classes of users of a common file (described above)
- Additional file manipulation in the form of command program conversion of core image file formats and DEC tape file formats is provided

3.2.5.3 H-6080 GCOS

The File Management Supervisor (FMS) provides a common file system for all processing performed under GCOS. FMS is a hierarchical catalog and file data structure. It is comprised of a System Master Catalog (total system file director) and User Master Catalogs. Below each User Master Catalog there can exist multiple levels of sub-catalogs. This structure provides a decentralized and extremely flexible file management system. Some significant features of this file system are:

- Concurrent updating of a single data base can be made by many programs without update conflicts
- Privileged file protection is provided by identifiers and attributes
- All mass storage allocation is controlled by FMS

- Restoration of files left incomplete by faulty application logic, hardware failures, or system interrupts is provided
- Program testing can be performed using production files in test mode

3.2.5.4 H-6180 MULTICS

The MULTICS storage system is a hierarchical file system augmented by a virtual memory. In this system, all data and instruction connectivity is accomplished by segmentation. All information in the system is organized into a hierarchical tree structure composed of segments connected by branches and links. File management (i.e., the Basic File System) in this system offers the user all the features of the conventional systems already discussed, plus the ability to make a segment (file) instantaneously shareable by being directly addressable in MULTICS programs.

3.2.6 LCF SOFTWARE TOOLS AVAILABILITY

Some of the software tools described in Volume 2 currently are available in each of the candidate host systems. However, this is a very fractional implementation, consisting primarily of the program development and integration tools on all but the H-6080 GCOS system. A summary of the current implementation is shown in Table 3-3.

Table 3-3. LCF Software Tools Availability

LCF Software Tool \ Computer System	H-6080 GCOS	H-6180 MULTICS	INFONET-1108s	DECSYSTEM-10
Compiler Generator (JOCIT)	Yes	No	No	No
Statistics Gatherer (JLMT)	No	No	No	No
Compiler Validation (JCVS)	Yes	Yes	No, but Impl. Cost is Negligible	Yes
Program Validation (JAVS)	Yes	No	No	No
Text Editor	Yes	Partial	Yes	Yes
Linker	Partial	Yes	Yes	Yes
Debugging	Partial	Yes	Yes	Yes
Translators	No	No	Partial	No

3.2.7 OPERATING ENVIRONMENT

3.2.7.1 Conversational Processing

The first of three operating environment requirements for the LCF host is conversational processing. Conversational processing will be required to be performed from the LCF and users terminals for the following:

- Local compiler and program validation from LCF terminal
- Remote compiler validation from LCF terminal
- Software problem report and receiver response from user terminal
- Compiler change proposal and receiver response from user terminal
- Remote data entry of language statistics from user terminal
- Language status query from user terminal

All three candidate hosts offer full interactive processing capabilities, communicating with both local and remote terminals.

3.2.7.2 Batch Processing

Batch processing will be required to be performed in LCF compiler generation and for language utilization analysis. Local batch processing is readily available in all three candidate hosts, while remote batch processing is available at the expense of additional software. The need for a remote batch capability for the LCF can be eliminated by selection of a host located locally to the LCF (i.e., H-6080 and H-6180 systems).

3.2.7.3 Timesharing

Timesharing is an LCF host option in lieu of a dedicated host computer for LCF implementation. For the LCF processing functional requirements envisioned, implementation of a dedicated computer system would be uneconomical. This is because a currently implemented large-scale timesharing system can provide the required system availability, processing power, and reliability at a fraction of the equipment and overhead costs of a dedicated system. All three candidate hosts offer timesharing capabilities that meet or exceed this requirement for the LCF host.

3.2.8 COSTS

3.2.8.1 Hardware Costs

The estimated new hardware costs for implementation of the H-6080 and H-6180 systems as the LCF host are shown below.

Unit	Unit Cost	Quantity	Total Cost
Teletypewriter Terminal	$6,000-$6,200	1 - GCOS 1 - MULTICS 1 - User	LCF $12,000-$12,400 User (each) $6,000-$6,200
TIP	$100,000	1 TIP User Terminal per User	User (each) $100,000 ÷ Number of TIP Users
TIP Interface Hardware	$10,000-$15,000	1 User	User (each) $10,000-$15,000 provided host is not currently on a TIP

New hardware costs for implementation of the INFONET-1108 or the DECSYSTEM-10 systems as the LCF host would require the use of batch terminals (as described above). Cost estimates are shown below.

Unit	Unit Cost	Quantity	Total Cost
Batch Terminal	$35,000-$40,000	1 - LCF Host	LCF $35,000-$40,000
Teletypewriter	$6,000-$6,200	1 - LCF Host 1 - User	LCF $6,000-$6,200 User (each) $6,000-$6,200
TIP	$100,000	1 TIP User Terminal per User	User (each) $100,000 ÷ Number of TIP Users
TIP Interface Hardware	$10,000-$15,000	1 User	User (each) $10,000-$15,000 provided host is not currently on a TIP
TIP Batch Interface Hardware	Not Available	1 - LCF	LCF - Not Available

3.2.8.2 Software Costs

New software costs also favor implementation of the H-6080 and H-6180 candidate host by a significant margin. This is because (1) some of the software tools have been implemented on the H-6080 GCOS system and (2) the requirement for the DECSYSTEM-10 or INFONET 1108 remote host involves local terminal support and ARPANET interface modifications costs. The estimated new software costs by system are given below.

Area to be Modified	H-6080 & H-6180	INFONET - 1108s	DECSYSTEM-10
Language Specification	50-64 mm	50-64 mm	50-64 mm
JOCIT	0	24 mm	24 mm
JLMT	28-62 mm	28-62 mm	28-62 mm
JCVS	0	1 mm	0
JAVS	0	48-66 mm	48-66 mm
Host Support Software	53-99 mm	9-33 mm	9-33 mm
Host - ARPANET Interface	6-12 mm	48-96 mm*	48-96 mm*
TOTALS	137-237 mm	208-345 mm	207-345 mm

*Includes local terminal support modification.

3.3 SYSTEM SELECTION

3.3.1 COMPARATIVE EVALUATION OF CANDIDATES

Each of the three candidate host systems was evaluated against the LCF requirements, and in some instances comparisons of the three candidate systems were performed. However, these comparisons provided no firm basis for selection of an LCF system because the relative importance of each requirement factor compared was not considered. The purpose of this section is to supply weighted values to each of the requirement factors, and to provide a side-by-side comparison of the candidate systems.

To compare the candidate systems, each of the LCF requirement factors was weighted based on CSC's experience with the pertinent hardware and software. Then, by using the total set of weighted LCF requirements, each of the LCF candidate systems was graded on a scale of 100 points. The results of this grading, illustrated in the system weighting matrix in Table 3-4, indicate that the H-6080/H-6180 host candidate is the logical first choice with a total score of 82 points. The second choice is the DECSYSTEM-10 with 63 total points. The seemingly-wide dispersion between the first and second choice is largely attributable to the terminal hardware and support software economy of using a host system (i.e., H-6180) located local to the LCF, and to the software economy of using a host system (i.e., H-6080) on which some of the LCF software tools are already implemented.

3.3.2 RECOMMENDED LCF SYSTEM

The H-6080 and H-6180 systems offer a number of significant advantages over the other two candidates, and are the systems recommended by CSC for implementation as the LCF host. The advantages of the recommended H-6080 and H-6180 systems are:

- Low implementation cost
- Minimum lead time in procuring new software
- Currently on ARPANET
- Maximum host environment utilization provided
- Maximum data security provided

Figure 3-2 shows the anticipated system interfaces for the recommended H-6080 and H-6180 LCF system.

Table 3-4. System Weighting Matrix

LCF Requirement Factor	Weighting Factor	H-6080 and H-6180	INFONET	DECSYSTEM-10
New Hardware Costs	12	10	4	4
New Software Costs	18	12	7	7
ARPANET Interconnection	14	14	0	14
LCF Software Tools Implementation	13	8	2	2
Operating Environment	12	10	8	8
User Interface	11	8	10	10
File Management	10	10	9	9
User File Protection	10	10	9	9
TOTALS	100	82	49	63

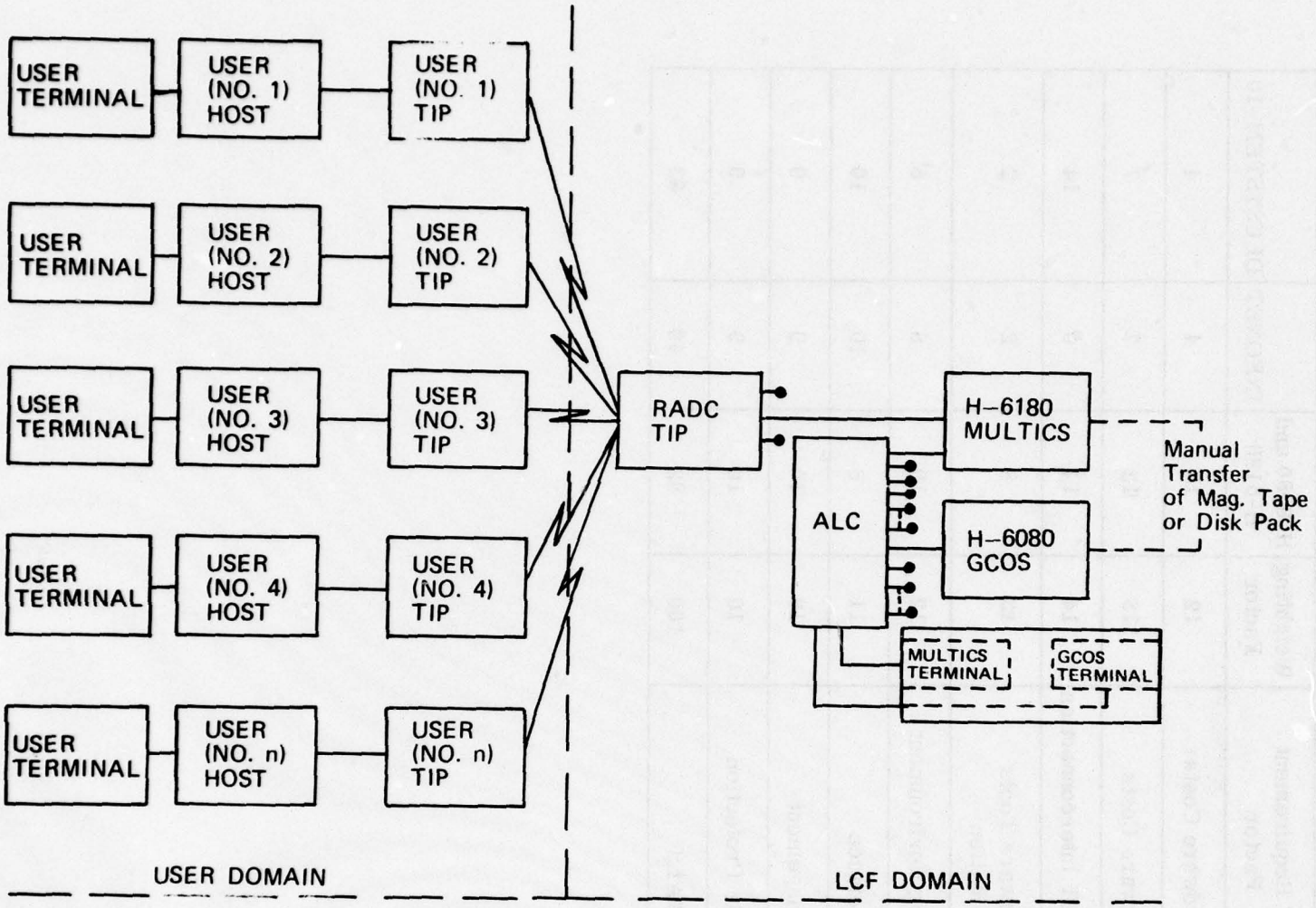


Figure 3-2. LCF System Interfaces

SECTION 4 - OPERATIONAL PROCEDURES

4.1 GENERAL REQUIREMENT

The LCF must be responsive to the user while maintaining a standard portable product. Together with the personnel and physical facilities, the operational procedures provide the means to accomplish this end. This section outlines the procedures necessary for an LCF and describes the basic set of procedures. Once an implementation is begun for a specific LCF, these procedures should be refined and expanded to describe the specific operations and to include the supporting software tools. Explicit operating procedures for the support staff will enable the LCF to use personnel from the military who will not require extensive training or tenure.

4.2 OPERATING PROCEDURES DESCRIPTION

The routine function of the LCF should be to process error reports and new user requirements, deploy current compiler versions, perform acceptance and regression testing and provide compiler software generation and maintenance. The procedures required to perform these functions are described in the following paragraphs.

4.3 LCF TEST SUPPORT

Support for new and evolving HOL software systems consists of correcting errors found in the systems, implementing new capabilities, distributing updated revisions of the systems, maintaining user documentation and procedures, and providing technical guidance in the correct and efficient use of the various features available in the systems. To accomplish this support, rigorous methods of acceptance must be employed. The recommended detailed procedures for performing acceptance testing for new or extensively modified HOLs are presented below. Also described are testing and acceptance procedures for minor modifications and documentation.

4.3.1 ACCEPTANCE TESTING

The identification of acceptance criteria is clearly as important an activity as writing the initial specification. The two are intimately related in that the former is derived exclusively from the latter. Ultimately, the acceptance criteria must be expressed in the form of acceptance testing, whose goal is to provide a systematic and objective measurement of the degree to which the compiler has met the specifications. One view of acceptance is that the compiler is either acceptable or not acceptable. However, that is both too stringent and too idealistic. Instead, degrees of acceptability must be recognized. In other words, a compiler may be usable long before it is completely error-free.

The acceptance testing activity is the logical culmination of a compiler implementation effort. The disciplined measurement of performance against requirements should be the principal governing activity. Acceptance test preparation proceeds with a systematic and exhaustive analysis of the specifications. It is often desirable to commission a group independent of the compiler implementation team to prepare the acceptance tests for a major effort; it may be accomplished successfully within the LCF staff or by an outside agency under contract to the LCF. This eliminates the tendency to prepare acceptance tests that are simply extensions of the design or development tests, and should aid in achieving an objective measurement. Also, where two different users are contributing to the same specification, there may be a conflict of interpretation. Guidelines are needed for resolving such conflicts. A Configuration Control Board (CCB) can provide the vehicle for mediation and resolution.

Whenever the scope of the compiler modification is such that a full acceptance test procedure is unwarranted or the change involves documentation and not software code, a simpler acceptance test procedure should be used. In the case of documentation changes that do not affect software code, the modified documentation with appropriately identified changes is subjected to review by

the user and configuration management for final approval, acceptance, and implementation. Minor software code changes must undergo an abbreviated version of the major acceptance test procedures.

In the course of preparing the guidelines for acceptance criteria specification, the following six acceptance test requirements should be examined:

- Analysis of the specifications
- Preparation of test plans and procedures
- Test preparation and validation
- Test materials available to developers and testers
- Preparation of test specifications
- Establishment of test controls

These are discussed in the following subsections.

4.3.2 ANALYSIS OF SPECIFICATIONS

Guidelines should be used in the analysis of the HOL specifications primarily to provide meaningful test categories. The specifications should identify the performance requirements for the completed compiler or its modification. Suggested categories include:

- Independent language form testing
- Composite language form testing
- Diagnostic tests
- Accuracy measurement
- Capacity measurement
- Optimization tests
- Code generation tests
- COMPOOL tests
- Tests for input forms
- Tests to generate all output forms
- Compilation mode tests

- Compiler option tests
- Debugging feature tests
- Library tests

4.3.3 PREPARATION OF TEST PLANS AND PROCEDURES

The scope of the testing is determined by the size, complexity, and criticality of the software modification. These guidelines should be used to consider the following points:

- Identification of test preparation team
- Identification of test management team
- Interface between implementers and testers
- Schedule of test delivery
- Schedule of required support software and hardware deliveries
- Other required resources (e.g., "war room" space, secretarial support, technical assistant support, etc.)
- Test case identification
- Test scheduling
- Operational script (test submission, test verification, result evaluation, error recording, status recording, etc.)
- Reporting methods
- Test materials

Test plans describe the tests required to assure LCF management and the customer that the compiler project will perform in accordance with the approved baseline specification. The plans provide for a sequence of tests applied from the time system components are being built and integrated until the total system is accepted.

For each test plan, the following information must be provided:

- An identification of the individual tests and their respective estimated start and completion dates
- An identification of the functions to be exercised and checked by each test (as related to the particular specification baseline)
- The scheduled date for the integration of each function

Scheduling should consider the interface requirements of each function (i.e., data interfaces through tables and files and control interfaces). The required availability of some functions before others (as specified in the requirements document), and the earliest time at which the function can be implemented and ready for integration, also should be scheduled.

A specification of testing environment (equipment, operator personnel, hardware configuration, special operating instructions) should be included in the test plan. The test plan should identify and schedule all software and hardware required to support the test to compensate for unavailability of critical functions or components, required hardware, supporting software, or other required test resources. The test plan also must identify resources required such as:

- Personnel required to prepare, execute, and evaluate the tests
- Support computer programs (i.e., test support and utility programs such as simulation, data reduction, memory dump programs, special loaders, and test input data generators)
- Type of equipment (including the computer) required during the test activity, plus the required operating time, duration, and availability of each equipment; the number of hours required per day, week, and month, plus information about the minimum turnaround time per use of the equipment

The LCF computer operator staff member should assist in preparing and scheduling the test plan and should see that the tests are executed. He coordinates with the LCF analysts and programmers to achieve successful test results.

4.3.4 PREPARATION OF TEST SPECIFICATIONS

The test specification provides the basis for preparing, conducting, and evaluating a given test. It describes the goals of the test, the necessary resources, the detailed test procedures, and the success criteria. A test specification must be prepared for each test identified in the Acceptance Test Plan. The test specification should be reviewed and approved in accordance with additional guidelines to be established.

In developing the test specification guidelines, the following points must be addressed:

- Test objectives - The purpose of the test, including the functions or specifications that the test intends to prove
- Test prerequisites - A specification of tests that must be completed and equipment that must be available before this test can be run
- Input values - The precise input values to be used or the method to be used in generating the inputs
- Initialization values - Static values for data items that are not part of the dynamic test input
- Output values - The expected output values that are considered to be indicative of a successful test; in cases where a given range or frequency is to be considered for success, the information should be identified

- Range of parameters - The upper and lower limits of numerical values; appropriate symbology for nonnumeric data
- Analysis techniques - Procedures to be followed in determining if outputs are acceptable

4.3.5 TEST PREPARATION AND VALIDATION

To eliminate unnecessary duplication of effort, the guidelines should aid in identifying existing sets of known tests for particular languages, e.g., the JCVS series for J-3 and J73/I JOVIAL. Testing extra-language features invariably requires the preparation of additional tests. Guidelines for test preparation must cover such subjects as coding standards, use of COMPOOLs for standard data descriptions and target parameterization, schedules, criteria for independence of subtests (i.e., are the results of one test required for a subsequent test?), method of result display (monitoring, stylized success or failure announcements, postmortem dumps, etc.).

The problem of validation is not an easy one. For standard tests, such as the JCVS series, the tests will have been validated through previous exercise. For modifications to existing HOLs, existing tests may suffice or may need to be modified. Where new tests are developed, the only hope of validation lies in the availability of an existing version of a compiler for the same language. The tests then may be partly exercised and debugged using that compiler.

Where there is no compiler available except the one under development, the guidelines may suggest use of prerelease versions of the compiler at least for syntax checking, if not for result verification. In this last case, the acceptance test period must combine compiler measurement with test case checkout. The guidelines should discuss how this condition may dictate the division of the acceptance period into two phases; the first to be dedicated to test case checkout with attention to fast, somewhat informal compiler error reporting and correction; the second to be dedicated to the formal acceptance measurement of the

compiler. In addition, the relevance of formal validation committees to this problem will be examined, and the results will be included in the LCF newsletter.

4.3.6 ESTABLISHMENT OF TEST CONTROLS

Test control is embodied in a set of procedures for use during the acceptance test phases of the project such that the test activity can be performed in a systematic and economic manner.

The basic activities to be controlled during the testing phase are:

- Application of tests to a given system or program
- Communication of information pertaining to discrepancies
- Analysis of discrepancies to determine the cause and solution
- Implementation and testing of the solution
- Reissuance of the system or program for further testing; providing the necessary documentation of its differences from the previous version of the system

4.4 MONITORING HOL SOFTWARE SUPPORT

The three principal control elements required to be monitored for compiler analysis, production, modification, and acceptance testing activities are:

- Software error processing
- Software change control procedures
- System release procedures

To allow the LCF to give efficient and timely service, a file must be maintained for each user. Each prospective user must provide the following information:

- Identification of the project(s) that the HOL compiler will support
- Hardware configuration
- Specific user contact for technical interface

- Type and criticality of application
- Availability and source of funding

Whenever any changes occur in any of the above, the user must notify the LCF. Periodically, the LCF should supply questionnaires to reaffirm or update this information.

Established control methods and procedures are summarized in the following paragraphs. Guidelines for controls should be derived and expanded from these summaries.

4.4.1 SOFTWARE ERROR PROCESSING

The Software Problem Report (SPR) is used to document and communicate to the appropriate analysts the information pertaining to discrepancies in the execution of a given test. The SPR (see Figure 4-1) or its equivalent should be used to report discrepancies discovered during the acceptance testing activity. The SPR should be reviewed by the responsible test management team to verify that the discrepancy is valid and that the necessary information was provided. The SPR then should be forwarded to the LCF manager or his delegate for resolution. The basic elements of the SPR must provide:

- Description of the discrepancy to the analyst such that he can determine variations between expected and actual output of the test run; differences from previous runs of the same test; suspected problem areas; and specific data causing the problem
- Specification of the run termination status
- Indication of the severity of the discrepancy
- Provision for a reference to the proper supporting material
- Allowance for a preliminary response to the discrepancy before its correction

SOFTWARE PROBLEM REPORT

SPR No. _____

PROBLEM: (Prepared By User)

Originator _____ Phone No. _____
(Name) (Organization)

System, Processor, or Component Failing or Project Involved _____ Computer _____ System Version ID _____ Test Case or Program ID _____

Classification

- ☐ Minor or Not to Specs.
- ☐ Major or Missing
- ☐ Information
- ☐ Revision Request
- ☐ Software Addition

Description of Problem (Attach additional pages if necessary–include line numbers of other identification of offended statements or data)

Correction Required By _____
Date

Enclosures

- ☐ Program Listings
- ☐ Run Deck
- ☐ Run Instructions
- ☐ Storage Map Listings
- ☐ Data Listings
- ☐ Online Output

Authorizing Signature _____ Date _____ Time _____
(Name) (Organization)

ANALYSIS: (Prepared by organization responsible for software)

Received Date _____ Time _____ LCF Charge Number: _____

- ☐ Software in Error
  - ☐ Restriction Required
  - ☐ Circumvention Required
- ☐ Software Not in Error Explain and Return to Originator
- ☐ Insufficient Information for Analysis. See Explanation
- ☐ Error Previously Reported On SPR No.
- ☐ Others, Explain

Explanation: _____

Analysis Time Expended:
Man Hours _____
Computer Hours _____
Computer _____

Estimated Cost of Solution:
Man Hours _____
Computer Hours _____
Planned Correction Date _____

- ☐ Not Approved
- ☐ Approved for Correction or Change

Signature _____ Date _____ Time _____
(Name) (Organization)

CORRECTION: (Brief description of work performed, including test cases used to confirm correction)

Solution _____ Modules Changed _____

Correction Time Expended:
Man Hours _____
Computer Hours _____
Submitted to _____

Work Performed by (Signature) _____ Date _____ Time _____

CONFIRMATION: (Correction Verified by: LCF MANAGER _____ Date _____ Time _____
(Signature)

Available in (Version ID) _____ Date Returned to Originator _____ Time _____

Figure 4-1. Sample Software Problem Report (SPR) Form

Since users will be reporting all problems electronically over a semi-automated teleprocessing network, the hardcopy printouts received at the LCF must be analyzed to determine if the reported problem is due to software error, or if it requires a specification change to accomplish. If the problem is deemed to be a software error, the hardcopy printout is stapled to an SPR form and processed the same as the development SPRs. If the problem is deemed to require a specification change, the LCF analyst must complete and submit a Language/ Compiler Change Proposal (L/CCP). The L/CCP is then submitted to the Configuration Control Board (CCB) for processing as a change request. In reporting problems, the user must submit the following information:

- Originator - Last name, initial, department, and telephone number of the person reporting the problem
- Activity - The site where the problem was observed
- Location - The reporting activity's address
- Date error found - The actual date of the discovery (not necessarily the date the HOLTR was completed)
- Problem description - A summary of the problem which can be used to enable the duplication of the problem
- Supporting data - The events and actual system responses which led to the discovery of the problem; specific related data such as listings, memory map, memory dump, etc., which will enable a programmer to recreate the problem
- Project - The project which was using the system for software development
- Project HOLTR number - For local project use, if desired
- System and version - The support system against which the problem is being reported (include a specific version identification and the revision number)

- Modification/patches - All patch modifications made to the system tape revision
- Impact - The effect the problem has on project software development:
    1. A fatal error; the system is inoperable
    2. A serious error -
        a. Error recovery is possible but difficult
        b. A moderately serious problem; the system is operable, but it is difficult to recover from errors
    3. A routine error; error recovery is simple
    4. A minor error or annoyance
    5. An insignificant error or no error at all
- Host machine - The machine on which the compiler was running
- Target machine - The target machine for which object code was being generated
- How found - The means used to discover the problem, such as listing check, document review, or compiler operation
- References - When reporting problems relating to conflicts between system performance and documentation, identify the specific referenced document by number, page and paragraph

The LCF assigns a control number to each SPR to help to monitor the flow of SPRs through a cycle of analysis, correction, and system update.

Within the LCF there should be a quality assurance (QA) group activity, which creates tests to reproduce errors reported on SPRs. These tests become a part of a basic QA program for the certification of all future compiler releases.

Technical LCF staff members screen SPRs to determine if the problems can be reproduced from the information provided by the user. The user-assigned

priority number also is reviewed to ensure it has been assigned properly. Priorities are as follows:

- Priority 1 - A fatal error; the system is inoperable
- Priority 2 - A serious error; one which makes error recovery difficult but not impossible; the system is operable, but it is difficult to recover from errors
- Priority 3 - A routine error; error recovery is simple
- Priority 4 - A minor error or annoyance
- Priority 5 - An insignificant error or not a reproducible error

During the initial analysis of an SPR, if the LCF development staff believes a user-assigned priority should be changed, the staff should contact the user by telephone for concurrence on the change. The staff should not make arbitrary unilateral changes to an SPR priority.

4.4.1.1 Error Analysis

In addition to problem reporting, the SPR is used for:

- The analysis of the problem resulting in one of the following conditions, with the appropriate explanation of the conclusion:
  - The software component was in error
  - The software was not in error; the test was in error, or the supporting software or hardware failed or the specifications were in error; the SPR was a comment or recommendation
  - There is not enough information available for proper analysis; in this case, proper instructions must be given to the originator of the SPR such that the required information can be obtained; the analyst may be required to work with the originator
  - The error was a duplicate of a previously reported error

- The changes required to the documentation, including document errors
- The manpower and computer time expended on the analysis
- An estimated cost of solution
- The resolution of the problem including a description of work performed, the testing performed, and a plan for the reintegration and system testing of the failing components

4.4.1.2 Error Status Report

A status report is prepared in accordance with Figure 4-2. Current and cumulative statistics on SPRs received, analyzed, and corrected are recorded on the first half of this report. The statistics should be derived from a review of each outstanding SPR by the appropriate language specialist.

The second half of the status report records current and cumulative statistics on SPRs reported against components in error. These statistics should give LCF management visibility of software problems and correction activity, as well as information pertaining to component reliability.

This report should be communicated to all users.

4.4.2 SOFTWARE CHANGE PROCESSING

4.4.2.1 Change Requests

Requests for changes should be communicated on standard change proposal forms (Figure 4-3). The same form is used to convey two kinds of requests, language changes and compiler changes.

Change proposals are completed and submitted by LCF staff members, either as an original change, or in response to a user problem. Users may submit change proposals directly, where it is obvious that a problem requires a specification change. The originator completes the front portion of the form The reverse side is reserved for use by the LCF development staff. Supporting

STATUS REPORT

Page ____ of ____

Project _____ Task _____ Account No. _____ Date _____

Customer _____ Project Start Date _____ Task Start Date _____

Task _____ Computer _____ Period Covered _____ Thru _____

SPR(s) RECEIVED			SPR(s) ANALYZED			SPR(s) CORRECTED		
	Current	Cum.		Current	Cum.		Current	Cum.
Major			Software in Error			Corrections Made; Verified		
Minor			Documentation in Error			Corrections Not Verified		
Information			No Error			Corrections Known Not Made		
			Insufficient Information			Corrections Not Known		
			Error Previously Reported			SPR's Returned		
			Under Analysis					
			Pending Analysis					
Total			Total			Total		

COMPONENT CHANGES AFFECTED BY SPR's

COMPONENT	No. SPR's		COMPONENT	No. SPR's		COMPONENT	No. SPR's	
	Current	Cum.		Current	Cum.		Current	Cum.

Version ID's and Dates of Language Released During Period _____

Approvals:

Task Leader Project Leader

Figure 4-2. Sample Status Report Form

LANGUAGE/COMPILER CHANGE PROPOSAL

Site Name and Address		
Project Name	Name of Originator	Autovon/Phone
Specify the Language/Compiler		

The proposed change is:

_____ Critical. (A major factor in the success and timely completion of the project)

_____ Important (Would greatly assist the project and provide greater system flexibility, but is not critical)

_____ Routine ("Nice to Have")

Describe the proposed change (Attach extra sheets if necessary)

Justify the proposed change (Include reasons for placing it in the Critical or Important categories)

Originator's signature	Date

Figure 4-3. Sample Language/Compiler Change Proposal Form (1 of 2)

THIS SIDE FOR LCF USE ONLY

Date Received / /	Internal C/LCP No.	C/LCP Meeting Date / /	Assigned to:	Circle Assignment Priority: Urgent Routine

Appraisal and recommended solution or reason for disapproval:

Alternate solutions:

Host System:	Site sensitive: If yes, circle:
Target System:	___Yes ___ No Originator only Hardware dependent User request

Action taken:

___ Special implementation for C/LCP originator ___ Approved for next major revision ___ Disapproved

Approximate target implementation date: / /	Authorizing signature	Date / /

Figure 4-3. Sample Language/Compiler Change Proposal Form (2 of 2)

documentation describing the requested change should be included with an L/CCP. The LCF librarian assigns an internal control number to each L/CCP to aid in monitoring its progress through the review, design, test, implementation, and release cycles.

4.4.2.2 Change Control

Change control is the most visible aspect of configuration management, since the people in this activity evaluate and approve or disapprove change requests, as well as requests for deviation or waiver of technical requirements. The purpose of change control is to prevent unnecessary or marginal changes while expediting the approval and implementation of the worthwhile ones, i.e., those that are necessary or promise significant benefit to the customer. Such changes are those that will:

- Correct deficiencies
- Significantly improve operational effectiveness or reduce logistic support requirements
- Result in substantial life-cycle cost saving
- Prevent slippage in an approved production schedule

In addition to change decision-making, change control includes the equally important functions of setting change priorities (i.e., emergency, urgent, or routine) and of ensuring that necessary instructions and funding authorizations are issued promptly for approved changes. These responsibilities are the domain of a Configuration Control Board (CCB).

A CCB should be established early in the development phase of an HOL project. During this phase it should consist of the LCF manager, his Air Force monitor, and selected LCF software analysts. After release of an HOL and related compilers to the users, each HOL user agency should have a member on the board.

The board is responsible for all decisions and actions pertaining to:

- Establishing the classification, type, and priority for each proposed change
- Determining the impact of each proposed change on all elements of the LCF
- Authorizing change implementation
- Review of all baseline document (specification) changes
- Scheduling the change
- Maintaining the status of changes and ensuring follow-up on the schedule

The LCF manager is the chairman of the board. After thorough analysis and discussion of the proposed change action, the chairman shall make the binding decision. The overall processing of a change proposal is shown in Figure 4-4.

4.4.3 SYSTEM RELEASE PROCEDURES

Newly developed or changed HOL software and documentation must be released in a controlled manner. If different versions of a language or its compilers are released to different users, a means of identifying and tracking the contents of the software must be provided. Similarly, the related documentation (if different) must contain identifying information for each user. Since maintaining different software packages can be very expensive (and easy to confuse), it is highly recommended that only one standard software package be released at any one time for an HOL. Should users find it necessary to make modifications for their own facility, they do so at the risk of not being able to ask for LCF assistance if problems arise.

4.5 PROCEDURES SUMMARY

To concurrently develop, operate, and modify HOLs, it is important that changes be made to the language in a controlled, systematic manner and that

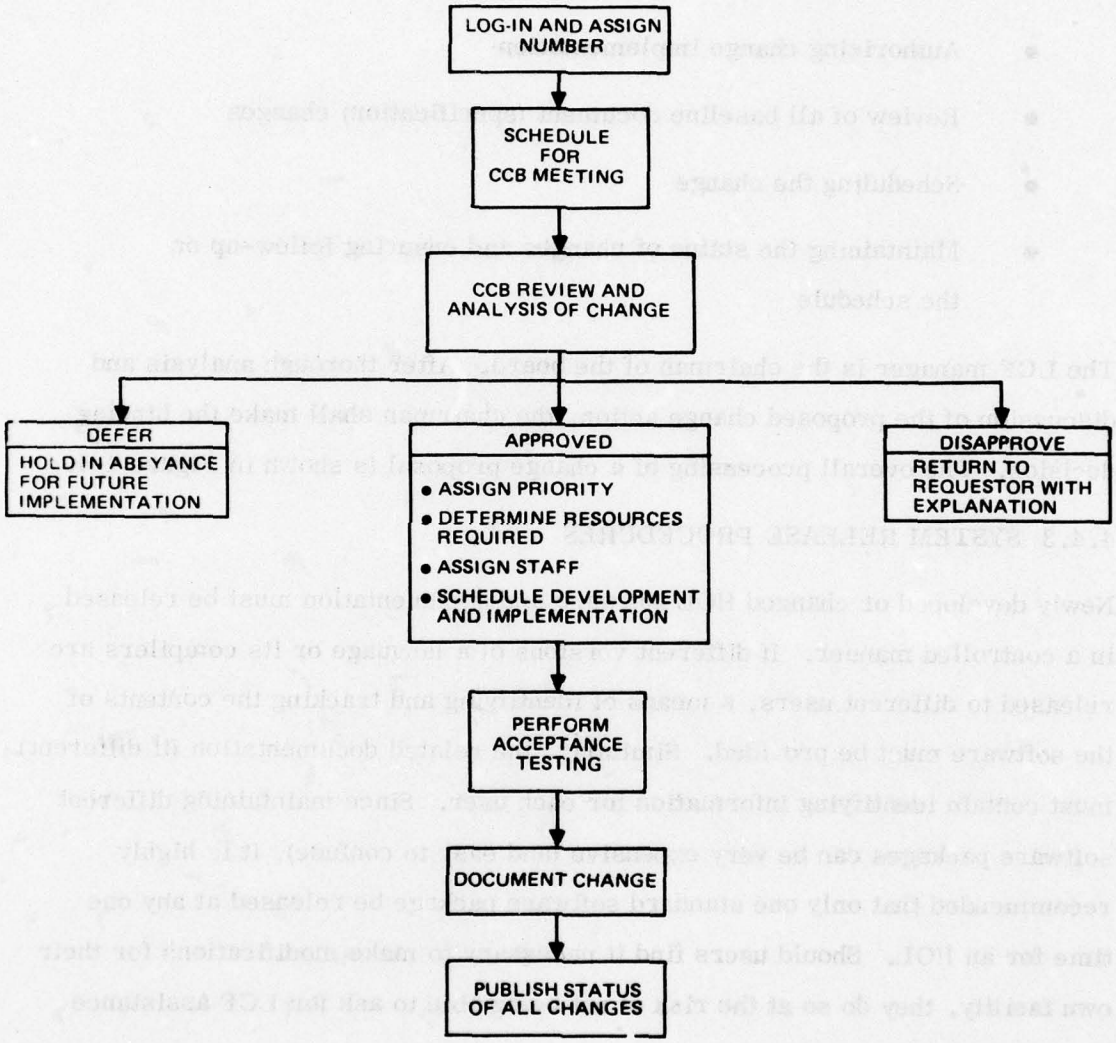


Figure 4-4. Functional Flow of Change Proposal Requests

information be collected to correct language deficiencies, improve language capabilities, and monitor relationships with various users.

All LCF development projects should have detailed change control procedures documented, reviewed, and approved by line management early in the development phase.

4.5.1 CHANGE CONTROL

Changes are usually initiated for one of the following reasons:

- The user's needs may change or become better known to him, and thus new requirements must be added or capabilities must be modified or deleted
- Use of an HOL is expanded and the requirements of the new users must be considered
- Documentation may be unclear or incorrect and thus must be modified
- An HOL implementation may not perform according to specifications, or the design may not meet the requirements
- During modification or development, the due date may be changed

An LCF control function should be established for change activity, and should be staffed by the librarian, who reports directly to the LCF manager. The librarian should have full responsibility to log, monitor, follow-up, and control all change requests and problem reports concerning HOLs, whether they concern compilers, hardware, communications, operating system software, applications software, operating procedures, or any other portion of the development activity. To discharge this responsibility, the formal procedures outlined must be established for collecting and processing problem reports and change requests.

4.5.2 COMMUNICATIONS

Through established procedures, the necessary information can be collected and handled promptly, providing feedback to originators as well as other user groups. The flow of information has been planned to enhance the communication of fundamental facts from and to the user. Section 2 has described this information flow, and it is summarized in Table A-9 in Appendix A.

Problem reports and change proposals may be originated by anyone associated with the system. In order to conserve analysis resources, management approval should be required for all requests. As each communication or request is received by the control point, it should be logged and assigned for action. The log should be monitored by the LCF manager to assure that timely responses to problems and requests are made.

4.5.3 STATUS REPORTS

Formal HOL status reports will be published in the LCF quarterly newsletter. This newsletter will provide users with information on the current status and future development of the higher order languages. It will also include news about recent HOL development acceptances, planned HOL development, changes made on scheduled revisions, and a summary status of active language change proposals. In addition, monthly status reports of SPRs and L/CCPs should be sent to all users, and any change that greatly impacts the user will be communicated by the most expeditious means available.

4.5.4 ANNUAL USER GROUP MEETING

An annual user group meeting should be conducted at the LCF. Among other things, this meeting should include formal announcements of training classes, new materials to be offered, and requests for future agenda items. Another purpose of the user group meeting should be to inform users of the current status of the higher order languages and to permit an exchange of information between the LCF and the user community.

SECTION 5 - FACILITY STAFFING, DESIGN, AND COSTS

The topics of facility staffing, design, and costs that are presented in this section apply to controlling a single HOL from a single LCF. First, the personnel staffing needs for the LCF are described in detail. This description includes the definition of the personnel organization structure, the personnel qualification requirements for each proposed staff member, and the manpower resources of Air Force, civil service, and Government contractors from which the personnel staff can be formed. Next, the facility design is addressed. This includes definition of the computer terminal equipment and office equipment required for the facility. Also included is a typical floor plan and the estimated air conditioning, electrical power, maintenance, and consumable item requirements for implementation of the facility. Then, cost estimates for the facility are developed. The method by which the cost estimating is performed differentiates between the costs of initial setup, ongoing operation, and continuing maintenance. The cost estimates developed consist of independent cost parameters that reflect all costs associated with facility hardware, software, communications, and manpower.

5.1 STAFFING AND MANAGEMENT NEEDS

5.1.1 LCF ORGANIZATION

The LCF must be staffed and managed in a manner that both supports the standardization of HOLs and recognizes the requirements of the user. The organization must be consistent with the procedures described in Section 4 and the present RADC organizational structure. Such an organizational structure for a single LCF is shown in Figure 5-1. Organizational and staffing considerations for multiple HOLs are included in Section 6.

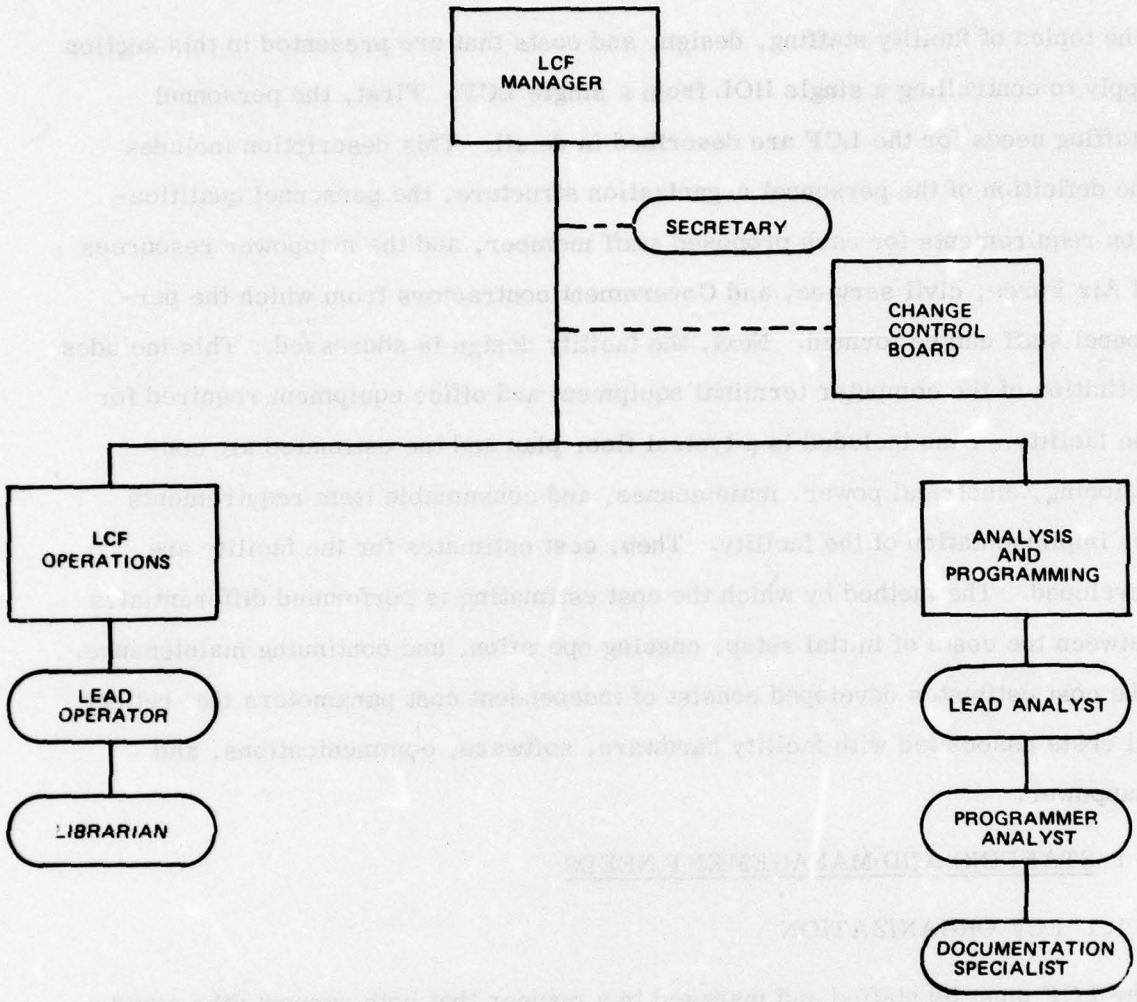


Figure 5-1. Proposed LCF Organizational Structure

The LCF organization must exist independently from the HOL users but responsible to the same higher authority. This ensures that neither group can enforce unacceptable requirements upon the other but that a common higher authority can mediate disputes. The recommended management techniques and organizational structure are such that these differences can seldom (and possibly never) occur.

5.1.1.1 LCF Manager

The LCF manager must be experienced in directing and monitoring computer system programs and activities involving one or more HOLs and preferably should have experience in language development. This position requires a bachelor's degree in computer science, mathematics, or a related science, or business administration with a strong mathematics or data processing emphasis. The manager will supervise two groups of personnel and preside over the Change Control Board. The groups are (1) Analysis and Programming and (2) LCF Operations. This position is the equivalent to Computer Systems Staff Officer, Air Force Specialty Code (AFSC) 5116; Computer Specialist, Civil Service GS-13; or Manager of Systems Programming in private industry as described in the A.S. Hansen, Inc., survey as reported in the January, 1976 issue of Datamation, Volume 22, Number 1, pp. 73-87. A specific job description for the LCF Manager's position is presented later in this section.

5.1.1.2 LCF Operations

The LCF Operations group is responsible for operating the hardware and communications system and for receiving, logging, and sending communications. The operations functions must be standardized, and a complete set of operating procedures must be prepared as discussed in Section 4. The personnel required to staff this group includes a lead operator, supported by an additional operator and managed by an operations manager where the size,

complexity, and multiplicity of HOLs require additional personnel. A librarian also must be included to record all incoming LCPs, CCPs, status inquiries, and user communications; to maintain status of all active and closed tasks; to support communications from the LCF to the user; to maintain current configuration status information; and to coordinate configuration changes transmitted to the user.

5.1.1.3 Analysis and Programming

The Analysis and Programming group is responsible for evaluating problems and requests for changes; answering user questions; performing and testing approved compiler changes; maintaining complete, current, and consistent documentation; and recommending compiler improvements. The personnel in this group must be language analysts, programmers, and documentation specialists familiar with HOLs, compiler construction, and the specific language or languages to be supported and controlled by the LCF. The number of each job classification depends upon the particular HOL or HOLs involved, and a separate manager may be necessary, depending on the size of the group.

5.1.2 MANPOWER RESOURCES

The recommended staffing of the LCF is predicated upon the availability of appropriately skilled personnel and well-defined job responsibilities and operating procedures. Knowledge and experience is especially critical in the language analysis and programming functions. A successful management background and an understanding of HOL concepts is necessary for the LCF manager.

The remaining positions can be defined better as to specific job requirements and supported by detailed procedures so that greater staffing flexibility is possible. If multiple HOLs are to be considered, the selection of the manager becomes the most critical consideration. The job description for each position is described below.

5.1.2.1 Language Control Facility Manager

5.1.2.1.1 Job Summary

The Language Control Facility manager administers and monitors HOL programs, including policy planning, program formulation, funding and direction of activities concerned with HOL analysis and control; software design, development, testing, maintenance, and documentation; and operation of computer facilities.

5.1.2.1.2 Duties and Responsibilities

The Language Control Facility manager performs duties and assumes responsibilities as follows:

- Formulates HOL standards and policies - Formulates and administers policies, concepts, and procedures to ensure effective and efficient use of HOLs and computer systems; keeps abreast of and adheres to current Air Force and DOD standards and regulations; evaluates technical problems and economic factors related to language research, various HOL adaptations, and computer systems applications; recommends changes to HOLs or HOL applications in response to user requirements, economic factors, and technological development; and establishes HOL objectives consistent with AF computer system objectives.
- Coordinates computer systems activities - Advises commander and staff on advanced concepts involving HOLs; develops and provides operating budget information; provides independent appraisals of HOLs and HOL applications; assists in the isolation of factual information; and recommends appropriate courses of action. Assures that proposed concepts fulfill user requirements and are technically feasible; provides cost estimates; assists in determining feasible development and implementation schedules. Schedules

and conducts configuration control meetings to review pending requirements, current status, and completed tasks for the Language Control Facility. Represents the commander in computer systems matters and maintains liaison with subordinate and higher headquarters. Maintains appropriate liaison with electronic data processing equipment manufacturers to obtain latest information regarding technological developments in equipment and techniques. Monitors the performance of contractual provisions concerning leased or purchased automatic data processing equipment.

- Monitors and directs computer systems activities - Provides direction and monitors progress of HOL control functions such as language analysis design, modification, documentation, development, testing, and application; manages language analysts and programmers and operation of the LCF computer processing and communications facilities; establishes programs and recommends procedures to ensure adherence to policy guidance and standards and to interpret and apply these for HOL user applications; establishes and monitors training programs for the LCF staff and users; evaluates HOL requirements to support proposed computer systems, performs technical audits of existing computer installations to assure standardization and to monitor HOL/compiler configurations, and recommends improvements based on observations.
- Chairs the Configuration Control Board

5.1.2.1.3 Qualifications

A bachelor's degree in a scientific or administrative discipline, preferably computer science, mathematics, business administration, or engineering; a master's degree is desirable but not mandatory; the manager must have knowledge of capabilities, limitations, costs, performance, and applications of HOLs

and compilers used in support of Air Force projects. The total educational and experience background must clearly demonstrate the ability to perform administrative, supervisory, managerial, and professional work of a high level of complexity in the field of computer science, with at least one year of experience at the equivalent of the next lower-level grade of data processing management.

5.1.2.2 Programming Language Analyst

5.1.2.2.1 Job Summary

The Programming Language Analyst provides HOL and compiler software expertise; analyzes, plans, and manages the development, maintenance and documentation of compilers, assemblers, executive and control programs, and supporting utility programs; plans and supervises programming, validation, and verification of HOL compilers.

5.1.2.2.2 Duties and Responsibilities

The Programming Language Analyst must perform the duties and assume the responsibilities outlined below:

- Formulates computer systems plans and designs - Develops plans and procedures for computer systems HOL design, development, test and evaluation, and program integration; determines performance specifications for HOL and relates system specifications to equipment and software characteristics; specifies and designs HOLs, defines equipment configuration, software requirements, communications interface, data requirements; data storage, retrieval, and maintenance methodology; data control techniques and documentation plan.

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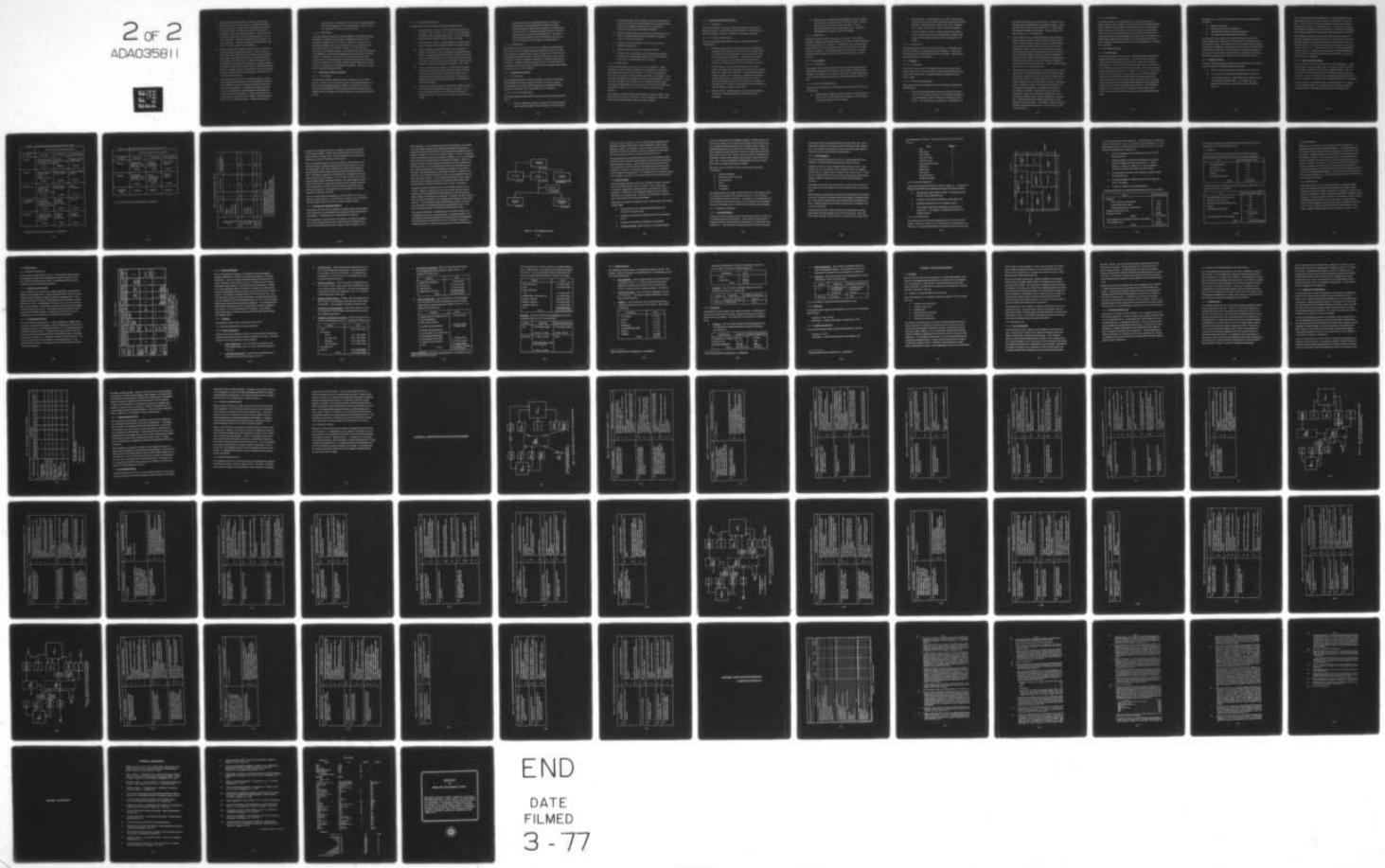

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- Develops HOL design specifications - Plans for, modifies, and maintains executive and control routines, assemblers, compilers, and utility programs. Divides program requirements into logical parts and determines how these parts will interact in terms of sequencing, timing, and storage requirements. Defines and works within known constraints, such as limited storage space, time, or input/output speeds. Develops and specifies tests to measure compiler performance . Produces program design specifications, flowcharts, and test procedures for documentation.

- Plans and designs HOL compilers and modifications - Confers with functional agencies requiring HOL support. Analyzes functional requirements and translates these into computer program specifications; designs and prepares program logic, symbolic formulation, block diagrams, and data format. Establishes and employs scientific programming techniques and flowcharts for computer programs to include selection and interfacing of executive control and operating routines. Designs, develops, and employs data- and error-reporting procedures, and test and evaluation procedures, and conducts tests to ensure proper integration.

- Directs HOL analysis activities - Directs the acquisition, development, operation, and maintenance of HOL development and maintenance. Confers with Air Force and other agencies concerned with HOL software development. Coordinates and consults with manufacturer's representatives concerning design and development of computer equipment and programs. Conducts studies and recommends changes in component units of compilers and application programs to ensure maximum efficiency. Remains conversant with

state-of-the-art developments, current Air Force and DOD standards, and improved techniques of on-line programming, computer utilization, information retrieval, and data acquisition.

5.1.2.2.3 Qualifications

A bachelor's degree in scientific or related discipline, with in-depth knowledge of capabilities, limitations, performance, and application of HOL and compilers used in support of Air Force projects. Must have at least one year of experience in a specific HOL to be controlled at the LCF; experience with one other primary HOL such as FORTRAN, COBOL, J-3, J73-I, J3B, PL/I, ALGOL or ATLAS is highly desirable. The educational and experience background must demonstrate a thorough understanding and working knowledge of HOLs and compilers, and familiarity with each of the primary HOLs specified earlier. At least one year of this background must include directing and supervising other analysts and programmers on complex computer systems projects that required estimating, evaluating, and scheduling project workloads. Experience in communications languages is highly desirable.

5.1.2.3 High-Order Language Programmer

5.1.2.3.1 Job Summary

The High-Order Language Programmer plans, designs, develops, modifies, installs, documents, and tests computer programs and language compilers, for high-order programming languages; coordinates, conducts, and directs the maintenance and modification of these programs and assists the Programming Language Analyst in planning, analyzing, estimating, and designing modifications to HOLs.

5. 1. 2. 3. 2 Duties and Responsibilities

The High-Order Language Programmer assumes the following duties:

- Designs programs - Interprets systems design and establishes program logic, coding techniques, and data formats for programming packages for HOLs and supporting programs. Determines organization and content of data files, tables, records, and items.
- Performs program coding - Prepares appropriate computer instructions according to program design, flow charts, and specifications.
- Conducts program testing and modification - Tests programs on equipment and compares results with program design specifications. Integrates component programs into complete systems and operates the system with simulated or live data to ensure program interaction according to systems design and test specifications. Makes required changes or modifications to programs as dictated by test results.
- Modifies and refines HOL compilers - Corrects errors and makes changes to reflect program improvements and responds to changes in the operational environment or system equipment as directed. Maintains and updates program documentation. Assists and conducts studies as required to determine need for, and feasibility of, system improvements.
- Installs and implements compilers - Implements compiler programs in an operational environment and conducts, supervises, or prepares on-site tests with live data to determine conformance to design specifications. Makes required changes as indicated by test results.

Coordinates and directs programming activities - Assigns programming and coding tasks and provides on-the-job training. Estimates program production cost in manpower, development time, and computer time. Coordinates personnel, equipment, and facility requirements to meet programming commitments. Develops and improves programming procedures and standards, maintains production controls, and reports progress in meeting objectives.

5.1.2.3.3 Qualifications

This position requires a bachelor's degree in a scientific or related discipline and at least four years of programming experience with at least three of these years engaged in the programming or design of compilers and at least one year of experience with an HOL compiler. Six months experience or more with the particular LCF compiler assignment is mandatory. Additional HOL experience is desirable. Completion of special training or study in the field of HOLs may be substituted for the specific degree specialization for an applicant with a degree in a nonscientific or related discipline.

5.1.2.4 Documentation Specialist

5.1.2.4.1 Job Summary

The Documentation Specialist maintains, upgrades, interprets, and develops documentation for HOLs and compilers; documents test results, compiler recommendations, and special studies; prepares user manuals and training materials; and compiles, edits, and publishes the LCF newsletter.

5.1.2.4.2 Duties and Reponsibilities

The Documentation Specialist assumes the duties and responsibilities described below:

- Develops, maintains, interprets, and upgrades HOL documentation using a working knowledge of HOL and computer systems concepts

to generate readable, clear, complete, and concise documentation. Analyzes and researches compiler problems and existing documentation to clarify compiler capabilities and user requirements. Schedules and coordinates documentation workload.

- Prepares compiler manuals and instructions that describe the use of HOLs, the compiler programming documentation, training procedures, and reference material.
- Organizes and edits documentation of formal test results and installation requirements.
- Prepares documentation of special studies as required.
- Compiles, edits, and publishes compiler information, problems, useful tips, and pending change applications in an LCF newsletter for LCF users, and applicable interested parties.

5. 1. 2. 4. 3 Qualifications

The Documentation Specialist must have a degree in a scientific or related discipline or a degree in English, technical communications, or related field with completion of computer science courses. Two years of programming experience or one year of systems programming experience is mandatory. Some experience involving HOLs, compilers, control or executive programs is mandatory, where the quality of the experience is more important than the quantity. Experience with the specific LCF HOL or one or more of the primary HOLs such as FORTRAN, COBOL, J73-I, J3-B, PL/1, ATLAS, or ALGOL is most desirable.

Past experience must have demonstrated the ability to organize, compile, write, and edit complex computer systems data, to work independently, and to produce clear and concise documentation within the required schedules.

5. 1. 2. 5 Data Processing Machine Operator

5. 1. 2. 5. 1 Job Summary

Prepares for operation, supervises, and operates computer hardware and peripheral equipment, and telecommunication equipment. Trains others in the operation of computer hardware. Schedules and coordinates workloads.

5. 1. 2. 5. 2 Duties and Responsibilities

The Data Processing Machine Operator assumes the following duties and responsibilities:

- Maintains operable status - Sets up equipment at the beginning of each shift and shuts down at the close of each shift unless operating in a multiple-shift environment where he accepts or prepares shift turnover instructions as applicable. Determines when equipment is in need of maintenance, and schedules and supervises such maintenance, including both preventive and emergency maintenance.
- Operates computer hardware and peripheral devices - Loads, mounts, operates devices and equipment such as consoles, keyboards, paper tape, magnetic tape, disk devices, teleprocessing equipment, keypunch, sorters, etc. as applicable. Communicates with system operating control program using standard job control language. Sets up and schedules required runs; determines and communicates operational status; recognizes and determines causes of malfunctions and takes appropriate steps to correct them.
- Maintains facility - Maintains supply records and assures adequate stock levels. Maintains equipment records and operational procedures.

- Supervises data processing machine personnel as required - Assigns work and reviews completed work for quality and quantity. Explains policy directives and conducts on-the-job training. Provides guidance and direction in processing computer runs. Coordinates with programmers, analysts, and the LCF manager.

5. 1. 2. 5. 3 Qualifications

This position requires a high school diploma or equivalent. Some college is desirable. Experience in preparing computer runs, operating computer hardware, and scheduling operations is mandatory. Completion of a basic data processing machine operator course or equivalent experience in operating data processing hardware is desirable. Telecommunications and remote-job-entry experience, as well as specific experience with the LCF hardware environment, is highly desirable.

5. 1. 2. 6 LCF Librarian

5. 1. 2. 6. 1 Job Summary

The Language Control Facility Librarian records all incoming and outgoing and internal communications such as Software Problem Reports, Language Change Proposals, Status Reports, CCB schedules and minutes, compiler configuration status, and other informal status inquiries and communications pertinent to the LCF.

5. 1. 2. 6. 2 Duties and Responsibilities

The librarian is responsible for the following items and must perform the duties outlined below:

- Maintain Status - Maintains a log and records all incoming requests, CCB actions, and final disposition of all Software Problem Reports, and Language/Compiler Change Proposals.

- Maintain data files - Files all SPRs, LCPs, CCPs, Status Reports, and pertinent documents including programmer and operator reference materials, configuration status, reports, test results, installation status reports, special reports, audits, and other pertinent data.
- Identify and Report Exceptions - Notifies appropriate personnel of overdue communications or status; prepares weekly status of open items and items closed during the previous week; prepares CCB agenda.

5.1.2.6.3 Qualifications

This position requires a high school degree or equivalent. Knowledge of data processing hardware and software terminology is mandatory. Completion of basic data processing and programming courses is desirable. Some hardware operating experience is also beneficial.

5.1.2.7 Secretary

5.1.2.7.1 Job Summary

The secretary reports to the LCF manager and provides clerical and stenographic support for the LCF staff; composes and prepares administrative communications; maintains files; records proceedings of configuration control board meetings.

5.1.2.7.2 Duties and Responsibilities

The secretary performs the following duties and assumes the responsibilities described below:

- Take dictation using shorthand, stenotype; transcribe from these sources or from dictating equipment - Take dictation of administrative communications, reports, directives, and telephone conversations. Record proceedings of conferences, staff meetings, and

committees by shorthand or stenotype machine. Transcribe, edit, and type minutes and administrative and technical reports. Prepare summaries and extracts of transcribed material. Prepare digest of transcripts of telephone conversations. Prepare stencils, ditto, offset masters, etc., for reproduction.

- Perform office services - Arrange appointments and conferences; prepare conference agenda; receive and refer telephone calls and visitors; assist and answer questions on office procedure and functions; extract information from files or prepare briefs of correspondence and reports; arrange for travel reservations; prepare travel orders and vouchers; initiate follow-up letters or memorandums; compose and complete replies to routine correspondence; segregate and route office mail and administrative communications; consolidate periodic reports; and review outgoing correspondence for adherence to style, format and policy. Requisition office supplies, repair services, or publications services.

- Maintain reference and administrative communications files - Obtain material such as stationery/supplies, reports, publications forms, and catalogs. Assemble briefs, tabulate, and file information pertinent to office activities. Examine, classify, code, index, and file documentation such as correspondence, messages, memoranda, reports, publications, forms, orders, schedules, catalogs, and requisitions, using alphabetical, chronological, geographical, organizational, subjective, or numerical systems, and cross-referencing. Prepare files maintenance and disposition forms. Establish and maintain tickler, suspense, special data, and locator files. Maintain pertinent office technical publications for ready reference and operational files. Post indexes, remove and/or insert changes to publications and directives. Receive, control, and file security documents.

5.1.2.7.3 Qualifications

This position requires a high school diploma or equivalent with courses in business English, typing, shorthand, and general office administration desirable. Ability and knowledge of shorthand or operation of stenotype or dictating equipment is mandatory; skills must be at a level to type at a rate of 50 words per minute or more and to take dictation at a rate of at least 90 words per minute. This position requires a good knowledge of spelling, grammar, punctuation, and standard office procedures and equipment. Previous experience in functions such as taking and transcribing dictation of official correspondence or recording also is desirable.

5.1.3 MANPOWER SOURCES

5.1.3.1 Considerations

The LCF must establish itself as the most reliable and efficient means of maintaining and improving existing compilers. Audit procedures can determine compliance and standardization of procedures but cannot ensure cooperation and acceptance. The LCF staff must establish a rapport with the various HOL users and within the RADC or applicable organization. There are three possible sources of personnel to staff the LCF: military, civil service, or Government contractor. It is not necessary that only one source be considered; however, the optimum mix would preclude any duplication of sources for any one job position, and ideally would use the same source within job families. Adequate communications and chain of command considerations affect the organizational staffing. The organizational operating cost and efficiency, and the personnel qualifications and continuity must be evaluated in order to select the best source. All of these factors have been considered in the recommendations that follow.

The staffing study is based on the premise that the following recommendations are adopted:

- Single shift operation
- Single operator hardware configuration
- Open shop environment for operation of hardware
- Pre-established hardware operating procedures

The organization is divided into the two logical functions: operations and analysis programming. Within these two functions it is not advisable to staff from different sources. The management of these functions must be consistent with the RADC or applicable organizational structure and with the staffing recommendations for its subordinate LCF organization. Therefore it is possible to have each of the three sources represented within the organization, as long as the functional responsibilities remain intact for each of the staff sources.

5.1.3.2 Relative Staff Cost

The cost of staffing the proposed organization from either of the three possible sources is based on the following remuneration sources:

- USAF pay and allowance tables for cumulative years of service
- U.S. Civil Service Commission General Schedule, October 1975
- Private Industry salaries, "Weber Salary Survey on Data Processing Positions in the United States," A.S. Hanson, Inc., as published in Datamation, January 1976, Volume 22, Number 1, pp. 73-87.

The Air Force rates do not include flight pay but do include dependents in the basic allowance for quarters (BAQ), and the basic allowance for subsistence (BAS). The Civil Service rates do not presume the adoption of the proposed 1976 pay raise of 6 percent. The private industry rates used for contractors do not include composite indirect costs nor profits. Estimates of these figures can be obtained through the Defense Contract Administration Services (DCAS).

For the purpose of this study, the composite indirect and profit costs were assumed to represent an increase of from 25 to 100 percent of the base salary. This was evaluated in the final consideration, but is not included in the rates quoted in this study. The rates for each source by equivalent job descriptions are shown in Table 5-1. A final evaluation can only be made by determining a specific contractor or contractors and preparing a Cost Analysis Worksheet, DA Form 3207-R, including cost elements other than staffing. A copy of this form is included in Appendix B.

5.1.3.3 Relative Staff Qualifications

The qualifications for the key staff positions are of utmost importance. These key personnel can determine whether the LCF concept is a success or failure. The remaining personnel can be classified as support personnel. Their job descriptions are more general and require a minimum amount of specialized background. Explicit work procedures for these support personnel ensure that employee capabilities are stressed rather than depth of specific skill backgrounds.

The positions that are designated as key are shown in Table 5-2. Also shown are the support positions. Each is ranked as to the estimated availability of qualified personnel. Special notice must be given to the rankings for key

Table 5-1. Estimated Annual Remuneration by Source (1 of 2)

LCF Organization Job Title	Source and Equivalent Position Title*		
	Air Force	Civil Service	Private Industry
Manager	Computer Systems Staff Officer, AFSC 5116, Major 12 yrs. $21,214	Computer Specialist, GS-13, Step 1 $22,906	Manager, Systems Programming $22,620
Analyst	Computer Systems Analyst, AFSC 5135A, Captain 10 years $19,195	System Analyst, GS-12, Step 1 $19,386	Computer Systems Analyst $20,904
Programmer	Computer Systems Programming Officer, AFSC 5144A, Capt. 8 yrs. $18,391	Programmer, GS-11, Step 5 $18,423	Senior Programmer $18,564
Documentation Specialist	Instructional Programming Technician, AFSC 75173, M/Sgt. 12 yrs. $14,025	Computer Specialist, GS-11, Step 2 $16,797	Analyst A $17,004
Operator	Data Processing Machine Operator AFSC 68550, Sgt. 4 yrs. $9,223	Computer Operator, GS-6, Step 1 $9,946	Computer Operator A $9,880

*Does not include indirect loading factors, as applicable.

Table 5-1. Estimated Annual Remuneration by Source (2 of 2)

LCF Organization Job Title	Source and Equivalent Position Title*		
	Air Force	Civil Service	Private Industry
Librarian	Data Services Specialist, AFSC 68150, Sgt. 4 yrs. $9,223	Computer Technician, GS-5, Step 4 $9,819	Data Control Clerk A $8,944
Secretary	Stenographic Specialist, AFSC 70450, Sgt. 2 yrs. $8,671	Clerk-Stenographer (Secretary) GS-4, Step 4 $8,774	Secretary, Class B $9,100
Organization Total	$99,942	$106,051	$107,016

*Does not include indirect loading factors, as applicable.

Table 5-2. Qualification Rankings by Source

	JOB TITLE	AF	CIVIL SERVICE	PRIVATE INDUSTRY CONTRACTOR
KEY (Specialized Skills)	Manager	3	4	4
	Analyst	3	3	5
	Programmer	3	4	5
	Document Spec.	3	4	4
Subtotal		(12)	(15)	(18)
SUPPORT (Capabilities)	Operator	5	5	5
	Librarian	4	4	4
	Secretary	3	4	4
Subtotal		(12)	(13)	(13)
TOTAL		24	28	31

0 = No qualified personnel available
1 = General qualifications not likely available
2 = General qualifications available
3 = Good general qualifications readily available
4 = Good specific qualifications readily available
5 = Excellent specific qualifications readily available

personnel as the rankings do not reflect capabilities of personnel as do those for the support personnel. Rather, these rankings reflect the availability of specific skill levels among a range of capable management level of personnel within each of the three recognized source structures.

There is a noticeable disparity between the ranking of a staff composed of all Air Force personnel and staffs composed totally of either contractor or Civil Service personnel. Upon closer examination it is shown that this disparity results from the relative ranking of the key personnel requiring specialized skills. The specific experience in developing HOLs, specifically a long-term experience in a particular language, is not as readily available in the services where personnel change assignments frequently. The same disparity is shown between civil service and contractor personnel in the key personnel positions. This is attributed to the presence in private industry of personnel with the specific HOL experience, and background in its development, for the initial installation considered in this study.

However, the most qualified personnel for a variety of HOLs may not be available from a single contractor. If more than one contractor is to be considered, the organizational structure and efficiency would be unduly impacted.

5.1.3.4 Recommended Organization Sources

Evaluating the data previously presented and considering future growth potential of the organization, the following sources of personnel to staff the facility are recommended. Justification for each recommendation is included.

The key personnel, consisting of the LCF manager, the analyst, the programmer, and the documentation specialist, must be able to be committed to the project for an extended period of time. Salaries, unless prohibitive, are of

lesser importance. The conclusion drawn from the data gathered and presented in this study indicates that the most qualified programmers and analysts are available from Government contractors with equally qualified managers and documentation specialists in civil service or private industry. However, considering overall organizational structure and efficiency of operation, it is not recommended that a branch of the organizational tree contain mixed personnel. Efficiency of operation is enhanced when personnel are working for the same organization to which they answer. It is recommended that all of the key personnel, the manager, analyst, programmer, and documentation specialist, be Civil Service personnel. Their qualifications are rated highly, the cost is competitive with contractor costs, and greater continuity of service can be guaranteed than with either of the other sources. For the purposes of this study, the LCF organization will be able to operate efficiently and compatibly with the related RADC organization and yet will have independence from the user organizations.

The support personnel qualifications are evenly distributed among the three sources. Continuity is much less a factor here because complete operating procedures will be available and the requirement for specific progressions, skills, training, and education are not as great. Therefore, the least-expensive source deserves consideration if it is consistent with the general organizational efficiency. The recommended staffing for the support positions is to use Air Force personnel for the operator and librarian positions but to use a Civil Service secretary because a more efficient relationship will result.

The resulting organization, as reflected in the chart shown in Figure 5-2, is an independent Civil Service group reporting to a commanding officer, with the Operations Section comprising Air Force personnel and the Programming and Analysis Section comprised of civil service personnel. This group, although independent of existing language groups such as RADC's Information

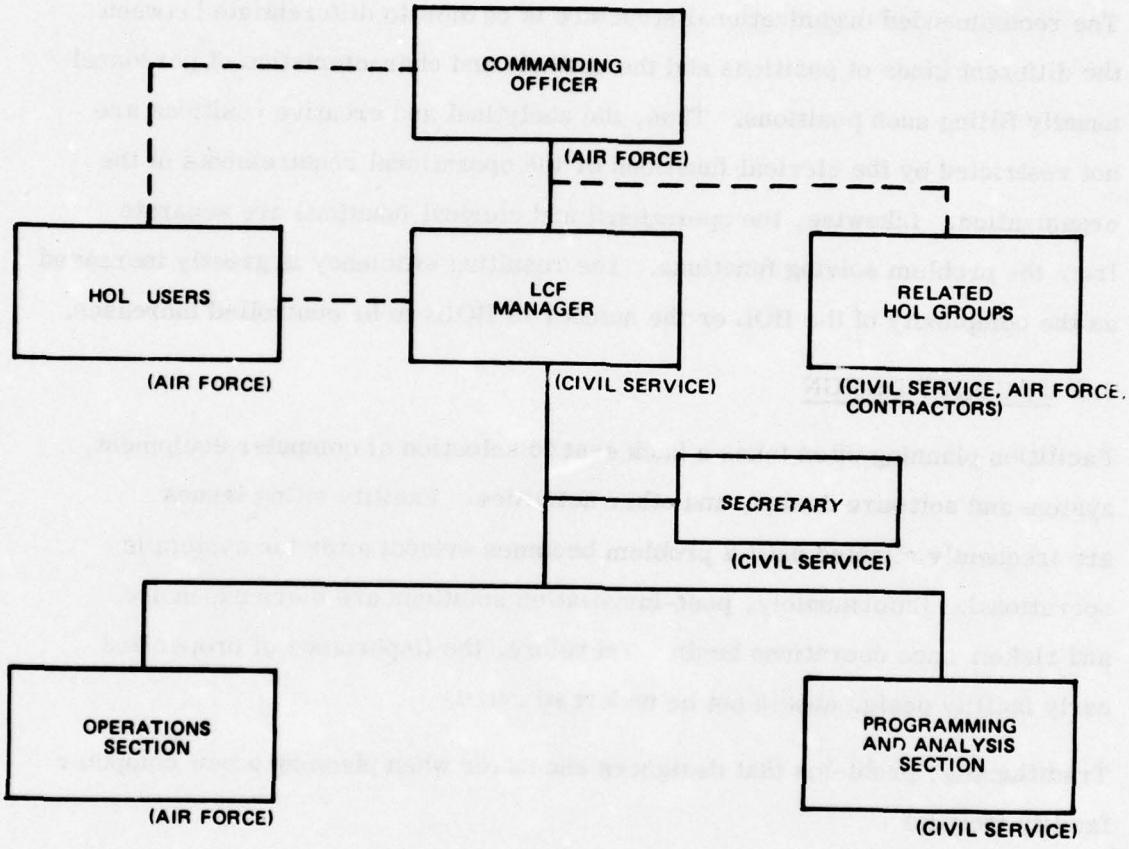

Figure 5-2. LCF Organization Chart

Sciences HOL group, should work closely with such groups regarding current applications, language developments, and the Configuration Control Board. Additional meetings, correspondence, and discussions should be encouraged within the LCF so that the staff does not become so bogged down with maintenance and auditing that it fails to provide leadership and direction.

The recommended organizational structure is careful to differentiate between the different kinds of positions and the aptitude and characteristics of personnel usually filling such positions. Thus, the analytical and creative positions are not restricted by the clerical functions or the operational requirements of the organization. Likewise, the operational and clerical functions are separate from the problem solving functions. The resulting efficiency is greatly increased as the complexity of the HOL or the number of HOLs to be controlled increases.

5.2 FACILITY DESIGN

Facilities planning often takes a back seat to selection of computer equipment, system and software design, and other activities. Facility siting issues are frequently slighted until a problem becomes evident after the system is operational. Unfortunately, post-installation solutions are more expensive and riskier once operations begin. Therefore, the importance of proper and early facility design should not be underestimated.

Traditionally, problems that designers encounter when planning a new computer facility include:

- Specifying power and air conditioning requirements for the facility in the evaluation stage
- Selecting an economical and reliable auxiliary power generating system
- Deciding to use overhead or underfloor air conditioning
- Designing grounding, static electricity, and acoustics systems

As can be seen from this list of problems, design of a computer facility is no trivial task. However, in the case of the LCF design, which is based on the use of computer terminals rather than a free-standing computer system, the anticipated problems are less severe and are of a different type. With computer terminals the requirements for overhead air conditioning and a primary power source are still valid. However, the requirements for underfloor air conditioning, auxiliary power system, and an acoustics system simply do not apply. Also, no special equipment or grounding system (such as a system ground plate or a copper grid system) is required.

The design of the LCF facility, therefore, focuses upon the following considerations:

- Equipment definition
- Facility floor space and layout
- Air conditioning
- Power
- Maintenance
- Consumables

An assumption made in this study is that the LCF will be located either adjacent to or very near the present RADC computer facility (i.e., the H-6080 and H-6180 facility) or similar organization. Accordingly, it was assumed that computer support services such as keypunch, card-to-magnetic tape, and magnetic-tape-to-card operations would be available at the computer facility equipment.

5.2.1 EQUIPMENT DEFINITION

5.2.1.1 Terminal Equipment

Computer terminals recommended for the LCF consist of two GE Terminet-300 (or equivalent) teletypewriter terminals. Both of these terminals should be dedicated terminals, plug connected to the Automatic Line Control logic (refer to Figure 3-2). One terminal will communicate with the H-6080 GCOS system

and the other with the H-6180 MULTICS system and the ARPA TIP. In this configuration, backup of each terminal can be provided by the other terminal. Also, the proximity of one terminal to the other will permit single-operator utilization in any of the LCF data processing functions.

5.2.1.2 Office Equipment

The office equipment requirements for the LCF include telephone services, typewriters, document reproduction equipment, and office fixtures.

Telephone services for seven personnel locations must be provided. These locations are: the LCF manager's office, secretary's office, two language analysts' offices, document center, operations room, and the library. In addition, one "hotline" telephone to be used only for communication with the users should be installed in a location easily accessible to the teletypewriter terminals.

Typewriters will be required in at least three LCF offices; one at the desk of the secretary to the LCF manager, one in the document center, and one in the library.

With the amount of documentation reproduction and distribution to be performed by the LCF, proprietary document reproduction equipment is considered essential. This document reproduction equipment should include the following features: computer printout form and letter-size paper feed, and multiple levels of copy size reductions.

Sufficient office fixtures to support the personnel requirements (7 persons) recommended for initial staffing of the LCF must be provided. Also a conference table and chairs will be required to accommodate LCF change control

board meetings in the facility. The estimated quantities for each furniture item are:

Item	Quantity
Desk	9
Desk Chairs	13
Waste Baskets	9
Conference Table	1
Conference Chair	8
Table (Operations Room)	2
Chalkboard	7
Status Board	4
File Cabinet	7
Document Cabinet	8
Punch-Card Cabinet	4

5.2.2 FACILITY FLOORSPACE

A typical floor plan layout for the LCF is shown in Figure 5-3. This floor plan allows for some office space expansion and provides the following features:

- LCF manager's office centrally located to all subordinate office functions, and to conference room
- Conference room facilities comfortably seating eight people
- Individual adjoining offices for the language analysts
- LCF manager's secretary located close to primary typing sources (i.e., LCF manager, documentation specialist, and language analysts)

5.2.3 AIR CONDITIONING

It is assumed that an overhead air distribution system will be used for the facility. In this type of system, air is supplied into an overhead plenum, and from there it is pumped down through the ceiling and dispersed into the rooms

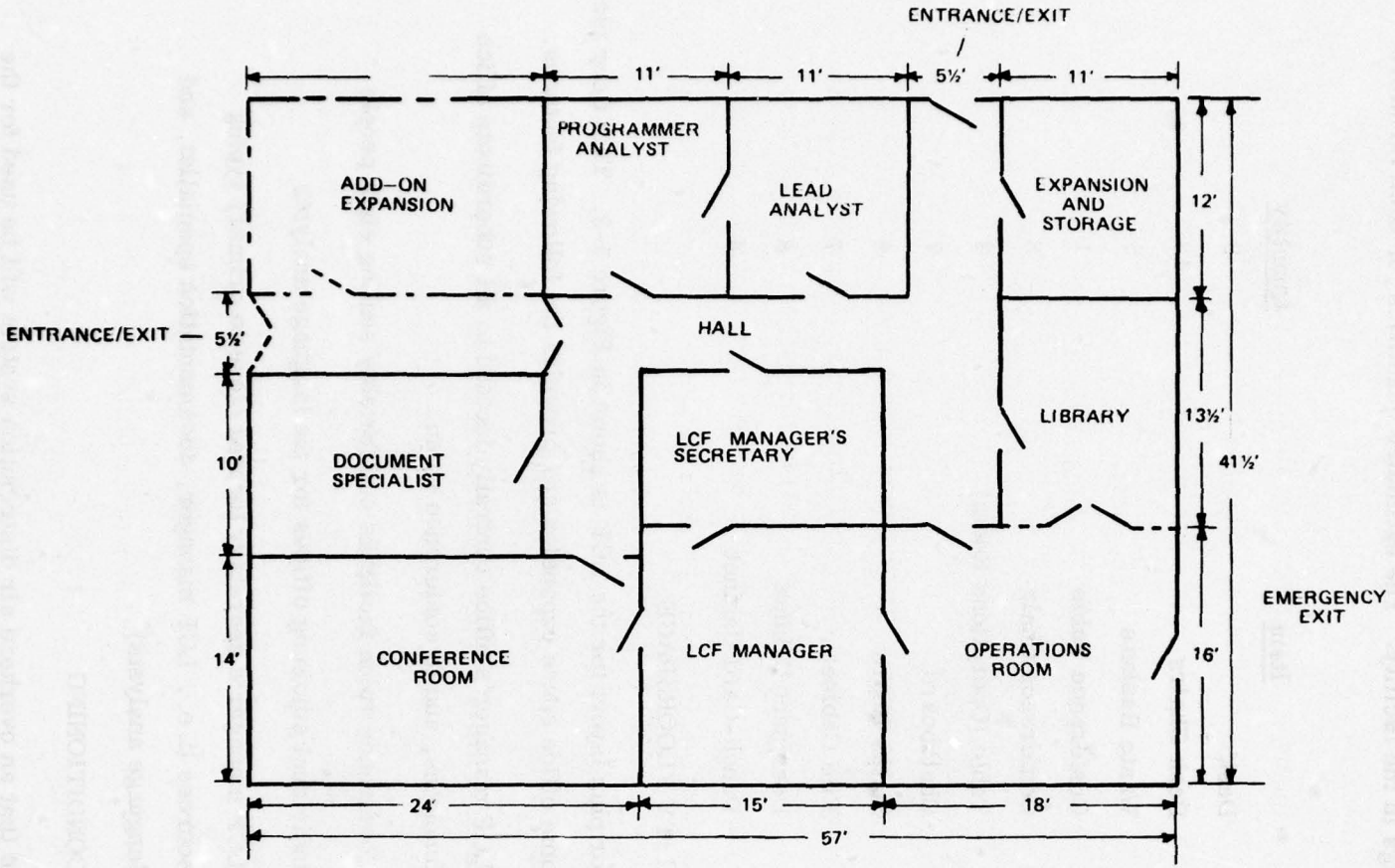

Figure 5-3. Typical Floor Plan Layout for LCF

to provide the required ambient temperature. Using this type of air distribution system, and based on the use of non-temperature-critical equipment, an accurate approximation of the air conditioning capacity required for the LCF can be made based on the following heat exchange factors:

- Each Kw of equipment power consumption results in 3413 BTU per hour heat load
- Assuming standard construction materials and one air change per hour ventilation, the other heat sources (i.e., lighting, outside air, conduction, radiation, etc.) can be estimated to be 30 BTU per hour for each square foot of floor space
- The heat output from people can be assumed to average 300 BTU per person per hour
- 10 percent contingency is added to account for fan energy, duct losses, and leakage
- 10 percent is added to account for latent gains

Using the above factors, the estimated total heat load of the LCF is as follows:

Source	Heat Load (BTU)
Equipment:	
2 TTY Terminals (35% load time)	6,681
3 Typewriters (35% on time)	5,364
1 Document Reproducer (30% load time)	12,013
Overhead Sources (2042 x 30)	61,260
Personnel (7 x 300)	2,100
Subtotal	87,418 (BTU)
10% Contingency (for fan energy duct losses, and leakage)	8,742
10% Latent Heat Gain	8,742
TOTAL	104,902 (BTU)

The resultant estimated air conditioning tonnage (104,828 divided by 12,000) required for the LCF is approximately 9 tons.

5.2.4 POWER

Utility source 60-HZ electrical power can be used throughout the facility. The estimated power requirements for the LCF are itemized as follows:

User	Power Requirement (KW)
Terminal Equipment	3.45
Typewriters	4.49
Document Reproducer	6.60
Lighting	6.13
Airconditioning/Heating	6.71
TOTAL	27.38 (KW)

A typical monthly power consumption estimate (based on a single-shift 176-hour month) for the LCF is shown below:

User	Power Consumption (KWH)
Terminal Equipment (35% load time)	344
Typewriters (35% on time)	276
Document Reproduction (30% load time)	620
Lighting	1,618
Airconditioning and Heating	3,543
Subtotal	6,401 (KWH)
20% Compensation (for peak loading)	1,280
TOTAL	7,681 (Typical Month)

5.2.5 MAINTENANCE

Maintenance of the facility will require support resources in two areas: (1) equipment maintenance and (2) building maintenance. It was assumed that the LCF would be located at RADC and that no construction or rental costs would be incurred. Building maintenance can be provided by maintenance personnel and equipment resources currently existing at RADC. Since maintenance of the facility building is to be performed by currently existing maintenance procedures, personnel, and equipment, further definition of these requirements is felt to be outside the scope of this study. The second type of maintenance, equipment maintenance, can be performed either by RADC maintenance resources, or by the vendors supplying the equipment. The equipment requiring preventive and corrective maintenance are: two teletypewriter terminals, three typewriters, and one document reproducer.

5.2.6 CONSUMABLES

Consumable items for the LCF include office supplies, equipment supplies, and the HOL reports and forms identified elsewhere in this report. Office supply stock includes such things as typing paper, writing pads, erasers, pens and pencils, paper clips, staplers and staples, rubber bands, hardbound notebook binders, etc. Equipment supply stock includes such things as typewriter ribbons, teletypewriter paper and paper tape, and copier paper. Spare equipment parts can best be supplied as required by the vendor or equipment maintenance source. The HOL report stock includes software problem reports, status report, language/compiler change proposal, and language statistics report.

5.3 FACILITY COSTS

5.3.1 GENERAL DESCRIPTION

Facility costs are summarized in Table 5-3. In the summary a total of eleven cost elements are included, and the application of each cost element to one or more of the three systems stages is shown. Descriptions of each of the cost elements are given in the following subsections.

5.3.1.1 Computer System Hardware

The cost elements in this category are: system enhancement, communications interface, and terminal devices. Systems enhancement refers to the cost of host computer hardware capability expansion required for hosting the LCF. These expansions include such things as an additional main memory module or an additional disk drive unit. Communications interface refers to the cost of host computer hardware additions or modifications required to interface the host computer with the communications network. An example would be the addition or modification of an I/O channel controller. Terminal devices refers to the cost of terminal devices to be installed in the LCF and the users' facilities.

5.3.1.2 Communications Network

The cost elements in this category are: network configuration, computer interface devices, and network use charges. Network configuration refers to the cost of adding a new user to the communications network, i.e., nodal equipment costs divided by the number of users. Computer interface devices refers to the cost of communications nodal equipment hardware modifications required to interface with a new host computer, i.e., specialized HOST-TIP interface hardware. Network use charges are the cost of using the communications network. In the ARPANET the use charge is a fixed annual rate rather than being based on internodal traffic quantities.

Table 5-3. LCF Costs Summary

SYSTEM STAGES	COST FACTORS										
	COMPUTER SYSTEM HARDWARE			COMMUNICATION NETWORK			SOFTWARE COMPONENTS[1]				MANPOWER
	SYSTEM ENHANCEMENT	COMMUNICATIONS INTERFACE	TERMINAL DEVICES	NETWORK CONFIGURATION	COMPUTER INTERFACE DEVICES	NETWORK USE CHARGES	INSTALLATION OF EXISTING PACKAGES	ADAPTATION/ MODIFICATION OF SOFTWARE	NEW SOFTWARE DEVELOPMENT	SOFTWARE ENHANCEMENT	OPERATIONAL STAFF
SYSTEM DEVELOPMENT				$100,000[2]	$10,000[2]–						
IMPLEMENTATION	0	0	$12,000 $12,400 $ 6,000[2] $ 6,200	DIVIDED BY NUMBER OF TIP USERS	$15,000	NA	0	87MM– 173MM	50MM– 64MM	32MM– 38MM	NA
ADDITION OF HOLS			$ 6,000[3] $ 6,200					0	0	122[3]MM– 218MM	
SYSTEM OPERATION											
CONTINUING OPERATION	NA	NA	$5,500[4]/ year	NA	NA	$60,000[5]/ year	NA	NA	NA	NA	$104,700[6]/ year
ADDITION OF HOLS			0								$37,800[3,6]/ year
MAINTENANCE											
HARDWARE	NA	NA	$3,880[7]/ year	NA	NA	NA				NA	NA
SOFTWARE			$750[2]/ year				8MM– 10MM/year	32MM– 40MM/year	8MM– 10MM/year		
ADDITION OF HOLS			$750[3]/ year				8MM– 10MM/year	32MM– 40MM/year	8MM– 10MM/year		

1 – SOFTWARE COSTS ARE EXPRESSED IN MAN/MONTHS OF SYSTEM PROGRAMMING
2 – THESE COSTS ARE APPLICABLE TO THE USER (NOT TO THE LCF)
3 – COSTS ARE EXPRESSED FOR ADDITION OF 2nd HOL TO SINGLE LCF
4 – TERMINALS ARE PURCHASED (THESE COSTS REFER TO RENTAL COSTS OF (3) TYPEWRITERS AND (1) DOCUMENT REPRODUCER
5 – THESE COSTS ARE APPLICABLE TO BOTH THE LCF AND THE USER
6 – BASE LABOR EXCLUSIVE OF ANY INDIRECT LOADING (i.e., OVERHEAD AND APPLICABLE G&A's)
7 – ALSO INCLUDES TYPEWRITER(s) AND DOCUMENT REPRODUCER MAINTENANCE COSTS

5.3.1.3 Software Components

The cost elements in this category are: installation of existing packages, adaptation/modification of software, new software development, and software enhancement. These cost elements collectively address the software costs of the three different types of software required: LCF software tools, program development support software, and the ARPANET protocol packages. Installation of existing packages relates to installation of existing LCF software tools. Adaptation/modification of software relates to each of the three types of software required. New software development relates to the LCF software tools. Software enhancement refers to software improvements, which perhaps are not mandatory for installation in the initial implementation of the LCF, but are extremely desirable in terms of increased operational capabilities. It is recommended that these software improvements either be incorporated in the initial implementation of the LCF, or as shortly thereafter as is possible. These software improvements relate to both the LCF software tools and the program development support software.

5.3.1.4 Manpower

This single cost element refers to operating personnel costs.

5.3.2 DETAILED BREAKDOWN OF COST ELEMENTS

5.3.2.1 System Development

All of the cost elements identified in Table 5-3, with the exception of network use charges and operational staff costs, apply to this stage of the system. The breakdowns for each of the applicable cost elements follow:

- System Enhancement. This cost element is not required in the initial implementation of the LCF, nor in foreseeable expansions to the LCF.
- Communications Interface. Likewise, this cost element is not required in the initial implementation of the LCF.

- Terminal Devices. The terminal equipment selected for the LCF are two GE Terminet-300 teletypewriters. The estimated cost of these terminals is $6,000 to $6,200 each. It is anticipated that the addition of a second HOL to the LCF will require that a third terminal be added to the facility.

- Network Configuration. This cost element is not applicable to the LCF, it does, however, apply to each user (providing that the user is not currently using the ARPANET). This cost is prorated based on the number of (TIP) users connected to a TIP, i.e., $100,000 divided by the number of TIP users.

- Computer Interface Devices. Likewise, this cost element does not apply to the LCF, but does apply to each user not currently using the ARPANET. The cost figure is $10,000 to $15,000 per user.

- Installation of Existing Packages. Three of the required LCF software tools (JCVS, JOCIT and JAVS) can be used as they are presently configured under GCOS.

- Adaptation or Modification of Software. This is the largest cost element for implementation of the LCF. It includes the following costs:

Software	Costs
JLMT	28-62 Man-months
Host Support	
SYMPL	6-9 Man-months
Obj. Link-Load	20-30 Man-months
Debugging	24-36 Man-months
Lang. Translator	3-24 Man-months
Host-ARPANET Interface	6-12 Man-months
TOTAL	87-173 Man-months

- New Software Development. This cost element relates to development of language specification software support material. It includes the following costs:

Software	Costs
Standard HOL Reference	6 Man-months
Tutorial Text	18-24 Man-months
Teaching Guide	8-12 Man-months
Supplementary Materials	18-22 Man-months
TOTAL	50-64 Man-months

- Software Enhancement. This cost element has a two-fold application. The first is the software enhancement required to significantly improve the initial operational capability of the LCF. This includes the following costs:

Software	Costs
Enhancement for retargeting JOCIT	30* Man-months
Code Straightening Dead Variable Analysis Extended Loop Optimizations Parallel Path Optimizations Use of COMPOOL by the Optimizer Miscellaneous Optimization	13* Man-months 8 Man-months
Source Module Text Editing	18 Man-months
Automated Code Generation	36-48* Man-months
JCVS	6-12 Man-months
TOTAL	(111-129MM) -(79-91MM) = 32-38 Man-months

*These modifications are currently being performed or are anticipated to be performed on other RADC contracts.

The second application of this cost element is the software enhancement, or improvements, recommended to accommodate the addition of new HOLs. The costs shown below reflect the generalized software tool recommendations described in Volume 2 of this report.

Software	Costs
JOCIT (generalize)	6-15 Man-months
JOCIT	12-36 Man-months
Reformatted Source Text	6-9 Man-months
Language Spec. (each new HOL)	6-12 Man-months
Program Validation	29-36 Man-months
Statistics Collection	28-62 Man-months
Language Translator	6-12 Man-months
JCVC	29-36 Man-months
TOTAL	122-218 Man-months

Summation. The sum of the cost elements applying to the system development stage of the LCF are shown below:

Facility	Single HOL	Addition of Second HOL
LCF	169-275 Man-months + $ 12,000 - $12,400	122-218 Man-months + $6,000 - $6,200
Each User	$ 6,000 - $ 6,200 + $100,000 divided by number of TIP users + $ 10,000 - $15,000	None

5.3.2.2 System Operation

The following cost elements apply to the operational stage of the system: office equipment, network use changes, and operational staff. The breakdowns for each of the cost elements follow:

- Office Equipment. This cost appears under the "Terminal Devices" cost element in Table 5-3. It does not relate to terminal device equipment, but instead refers to rental costs of the three typewriters - $1,080/year and the document reproduce - $4,020/year.
- Network Use Charges. This cost element is applicable to both the LCF and the user. The charge for using the ARPANET is a fixed annual charge of $60,000.
- Manpower. This cost element refers to the operational staff personnel costs identified in Section 4 of this volume. These include the following:

Staff Member	Costs[1]
LCF Manager	$ 22,906
Secretary	$ 8,774
Analyst	$ 19,386
Programmer	$ 18,423
Documentation Specialist	$ 16,797
Operator	$ 9,223
Librarian	$ 9,223
TOTAL	$104,732

[1] Does not include indirect loading factors, as applicable.

Operational staff additional estimates for controlling a second HOL from a single LCF includes the following manpower:

Staff Member	Costs[1]
Analyst	$19,386
Programmer	$18,423
TOTAL	$37,809

- Summation. The sum of the cost elements applying to the system operation stage of the LCF is shown below:

Facility	Single HOL	Addition of Second HOL
LCF	$65,500 + $104,700[1]	$37,800[1]
Each User	$60,000/year	None

5.3.2.3 Maintenance

The following cost elements apply to this stage of the system: terminal devices, installation of existing software packages, adaptation/modification of software, and new software development. The breakdowns for each of these cost elements follow:

- Hardware. This cost element includes hardware maintenance of the two teletypewriter terminals (and the three typewriters and document reproducer):

Hardware Item	Single HOL	Addition of Second HOL
Teletypewriter Terminals (2)	$1,500	(1) $750
Typewriters (3)	$ 180	None
Document Reproducer	$2,220	None
TOTAL	$3,880/year	$750/year

[1] Does not include indirect loading factors, as applicable.

- Software Maintenance. Three software component elements will require continuing maintenance. This requirement is four to five programmers working full time in maintenance of a single HOL.
- Summation. The sum of the annual cost elements applying to system maintenance for the LCF is shown below:

Facility	Single HOL	Addition of Second HOL
LCF	48-60MM(Systems Programming) $3,880/year	48-60MM (Systems Programming) $750/year
Each User	$750/year	None

5.3.3 LCF MONTHLY OPERATION AND MAINTENANCE COSTS

5.3.3.1 Single HOL

The estimated monthly operation and maintenance costs for an LCF controlling a single HOL are:

Operation: $5,458 + $8,725[1]

Maintenance: 4-5 Man-months (Systems Programming) + $324

5.3.3.2 Addition of Second HOL

The estimated additional monthly operation and maintenance costs are:

Operation: $3,150[1]

Maintenance: 4-5 Man-months (Systems Programming) + $63

[1] Does not include indirect loading factors, as applicable.

SECTION 6 - MULTIPLE HOL CONTROL

6.1 ANALYSIS

While this study has determined the feasibility of an independent language control facility for controlling language modifications, the issues of how many languages are to be controlled at a single facility, or how many facilities are required, must be addressed. The objectives to be considered are effectiveness, operating efficiency, accessibility, and cost.

6.1.1 SINGLE LCF CONTROLLING MULTIPLE HOLs

Some of the problems to be considered in operating a single LCF site for multiple HOLs are:

- Communications requirement
- Hardware requirement
- Staffing impact
- Physical facility requirement
- Accessibility to the user
- Software tools requirement

The number of communications, the locations and operating shifts of the users, and the criticality of the problem communication per user application must be considered in determining the impact of an operation to control more than one HOL from a single location. A 16- or 24-hour shift communications operation should be considered, depending on the user locations and the criticality of their applications. For the purpose of this analysis, future growth potential has been considered an important factor. A generic impact assessment for the addition of each HOL is difficult to derive. Generally, when maintaining at a single facility an additional HOL that is of like configuration to an HOL already controlled

at that facility, the cost is minimal. In such a case the primary cost factors involve staffing two additional persons at an annual cost of $37,809 and the addition of one terminal device at an annual cost of $6,000 to $6,200, a total annual increase of approximately $44,000.

The impact of storage requirements, hardware capabilities, and increased software tools and compiler software must be evaluated as each new HOL is added to an LCF's control. As the number and complexity of HOLs controlled by a single LCF increases, the requirement for supporting hardware increases. Batch terminals and minicomputer support at the LCF should be considered as likely necessities for controlling very many multiple HOLs from a single site, so that the host computer could be relieved of many preprocessing steps. Increased storage requirements would have to be levied on the host machine to support the added load of software tools and compilers.

Controlling all HOLs from a single LCF might even justify an HOL's own separate host hardware. Increased support hardware requirements cannot be determined by simply increasing single HOL support hardware by a factor of the total number of HOLs. Some sharing of capability can be used up to the point where the HOL demands exceed the equipment capabilities.

6.1.2 MULTIPLE LCFs

6.1.2.1 LCFs for Each HOL

To control each HOL from a separate location defeats the intent of the LCF study. It presents the necessity of fully funding each separate facility with duplicate staff, facility, and hardware requirements. It also presents a problem in controlling and standardizing the duplicate LCFs, requiring either that a separate manager be over all facilities or that the manager of one facility be charged with administrative responsibility for the remainder. Standardized procedures would help to ensure handling each individual HOL properly and to increase transferability of application programs between facilities using

that HOL. However, each LCF would likely tend to protect its own interests and promote its own HOL. Outside the fact that the LCF staff will have an interest in generic HOLs, it is anticipated that they cannot avoid developing the same self-interested, parochial viewpoints presently exhibited by the various HOL users. Such a position is natural from a staff serving a particular group of users and not directly responsible for the interests and requirements of other users.

Multiple LCF facilities, if deployed on the basis of language served, still have to consider that the users may be physically located in diverse areas of the country. To provide LCF personnel at each user site is an unmanageable and untenable solution that offers little advantage over that of the user having his own in-house language expert. Occasional travel to the user sites should eliminate any requirement for permanent on-site HOL analysts. However, any application judged critical enough to require a permanent on-site analyst should be assigned an LCF-controlled analyst for whatever period is deemed necessary.

6.1.2.2 Alternative Multiple LCFs

Alternatives to a separate LCF for each HOL are (1) to configure LCFs to support similar languages or (2) to have a separate LCF to support each of the major Air Force application areas. The first alternative seems logical and is a recommended approach to increasing the initial LCF. However, once there is an operable organization supporting more than one HOL, it would seem a natural progression to expand to additional HOLs even though those HOLs might not share a familiar relationship with the original HOL. The second alternative offers no advantage over controlling all HOLs from a particular site, because most application areas use more than one HOL and usually these HOLs support different kinds of applications.

6.1.3 SINGLE LCF RECOMMENDATION AND ADVANTAGES

AFR 300-10 specifies three standard Air Force HOLs, FORTRAN IV, COBOL, and JOVIAL/J3. The DOD High-Order Language Working Group will choose a single standard HOL or at least as few as possible. Recommendations from this group will determine any additional LCF requirements. If the three AF standard HOLs are considered, and the potential LCF considerations include the related J73-I and J3B, the specialized ATE HOL, ATLAS, and a possible yet-to-be developed HOL-like communications language, then the anticipated maximum number of HOLs considered for control by a single LCF can be limited to seven. The advantages to operating from a single LCF to control a variety of HOLs are many and the most significant advantages are discussed below.

6.1.3.1 Standardization

By controlling a single HOL, an LCF can help to achieve standardization within the user community for that HOL. However, by controlling multiple HOLs, especially those with similar user applications supported by related HOLs or versions of the same HOL, an LCF could provide valuable assistance in recognizing the requirements of the user and matching those to the capabilities of the available HOLs. In those applications where little or no present language standardization or selection criteria exist, the LCF could provide a valuable insight into the selection and adoption of appropriate HOLs. This would not only curb the proliferation of different HOLs, but also would eliminate the unnecessary use of assembly languages (where their selection was one of expediency rather than necessity). By funnelling all HOL requirements to a single group, a basic HOL requirement definition versus an HOL capability profile should evolve - such that desirable characteristics of each HOL might be made available in all HOLs, eventually consolidating where possible.

The LCF should become the ultimate source, cognizant of: the HOLs used, the shortcomings of each HOL as recognizable from approved deviations or requests for deviation, and applications not amenable to HOL use. Statistics and continuing studies can help to provide a HOL standardization guideline and capability description that could provide the baseline for future language selection and eventual conversion. Thus, it is important to have one organization cognizant of the broad spectrum of AF user languages and applications. Table 6-1 shows the major languages used by application.

6.1.3.2 Portability and Transferability

Control of HOLs from a single location enables the identification of nonstandard features in the various versions, periodic audit and reassessment of those features, and a centralized background of knowledge about various target machine requirements. Application programs operable in a particular HOL version will have any nonstandard features identified through the compiler, and the LCF staff can assist the new user in determining whether those deviations are necessary for his application and target hardware. Thus, the LCF can assist in the transferability of user software from one user to another.

The most difficult problem encountered in portability of HOL compilers exists in varied capabilities and idiosyncracies of the target hardware configurations. The requirements for intimate knowledge of the various target computer assembly languages or machine language is of major consideration in selecting the LCF staff. However, the possibility of staff selection by target machine language would defeat the purpose of the LCF, as the major HOLs are each available on a wide variety of hardware configurations.

In the few situations where an HOL is used on a peculiar target configuration not applicable to any other HOLs, it is no greater an impact to consider staffing an additional support language programmer at the LCF than to staff one in the field. The larger the number of HOLs being supported by the LCF, the larger becomes

Table 6-1. Major Language Use by A/F Application

APPLICATION AREA	LANGUAGES								
	ASSEMBLY	FORTRAN	JOVIAL/J3	SPL	COBOL	HAL/S	J3B	J73	ATLAS
Operational Flight Programs (OFP)	#	x		x		x	x	x	
Command & Control (CC)	#	#	*		*			*	
Communications (COMM)	x	#	#						
Range Support (RS)	#	*							
Automatic Test Equipment (ATC)	x	#							x
Simulator & Trainer (ST)	x	#							

* Indicates standard language specified in AFR 300-10, adopted as standard, or recommended standard

x Indicates major use

# Indicates some use

the number of target machines. However, there will be much overlap; therefore, the programmers could be used according to target language, each being familiar with the general language constructs of HOLs and working from the predesignated semantic and syntactic constructs verified and approved by the HOL analysis. A balance could be obtained by cross-training programmers in multiple target languages, especially the lesser-used ones. Extensive development and use of cross-compilers provides automated portability. The LCF would be tasked with design, modification, and maintenance of these cross-compilers.

6.1.3.3 Supporting Software Tools

The development and maintenance of the software tools required to support the LCF represents a major portion of the effort in implementation. To the degree that these tools can be generalized and standardized themselves, such that one tool will handle more than one HOL, the more cost-effective and efficient will be the resulting LCF implementation. Development of specialized tools for each language should be discouraged much as the LCF hopes to discourage unnecessary proliferation of multiple HOLs and specialized versions of HOLs. This can only be accomplished by recognizing at the outset that combinations of HOLs are anticipated.

While expediency and availability of software tools to support the initial LCF might dictate the adoption and modifications of existing software, steps should be taken to define multi-purpose software tools that can be adapted to support a multiple HOL LCF. Volume 2 of this report describes the impact of multiple HOLs on JOCIT, one of the software tools evaluated in this study. This tool already has a generalized multi-HOL design concept easily adapted to the JOVIAL languages and, with modifications, to others.

6.2 COST CONSIDERATIONS

The cost of operating several LCFs versus operating a single LCF must be considered with regard to the impact on staffing, the physical facility, the hardware

requirement, and the workload efficiency. In addition, costs should not take priority over purposes, as there are potential advantages and hidden cost savings through increased standardization. (A summary of increased costs for adding a second similar HOL at a single facility is shown in Table 5-3.)

6.2.1 STAFFING CONSIDERATIONS

Staffing a single LCF facility to control multiple HOLs would not require additional management. It is recommended that several analysts be redesignated as lead analysts to provide a base for forming language teams. These teams should not be fixed, but should be constructed to support specific tasks and staffed by appropriately experienced programmers and analysts. Continuous cross-training of programmers and analysts should be conducted to provide additional support for the more active HOLs and target hardware.

Initially, one analyst and one programmer should be added to the staff for each additional HOL. However, for the lesser-used HOLs, staffing may be shared, with the increased staffing requirement assigned to the support of more volatile HOLs or widely used target hardware. Actual LCF operating experience will help to determine the final staffing requirement. No additional personnel will be required to staff the operations and librarian functions. One or two additional documentation specialists will be required to support multiple HOLs, but not one per HOL. Documentation of like HOLs can be performed by the same staff member. An additional typist might be required to support the documentation and clerical workload.

6.2.2 HOST HARDWARE IMPACT

The assumption was made in the initial hardware recommendation that sufficient time would be available to support a single-HOL LCF. The impact of handling a larger number of HOLs for a larger number of users would put a much larger

requirement on this host hardware. It is likely that sufficient time is not available to handle all of the HOLs addressed in this section. Based on actual usage of the initial LCF, projected usage should form the baseline for determining whether a dedicated host machine or, at the least, a full batch terminal capability is justified. The compilers themselves and other support software should be made host-computer-independent so that they can themselves be retargeted. The communications equipment interface is not affected appreciably by the number of HOLs or LCF locations, as the MULTICS and GCOS systems can adequately handle the anticipated additional communications interfaces. One terminal device per HOL is recommended for each HOL controlled by a single center and at least one communications center per physical LCF location.

6.2.3 PHYSICAL FACILITY

Multiple LCF locations would require replicas of the physical facility described in this document. By combining control into a single LCF the physical requirements would need to be expanded to accommodate a batch terminal and additional teletypewriter terminals. The square footage would have to be increased by the amount necessary to house each additional analyst and programmer required to support each additional HOL. The supporting utilities and furnishings to provide for the additional personnel would have to be included. The resulting cost for a single larger facility would be less than for duplicate multiple facilities by virtue of the smaller staffing.

APPENDIX A - COMMUNICATIONS OPERATIONS AND PROCEDURES

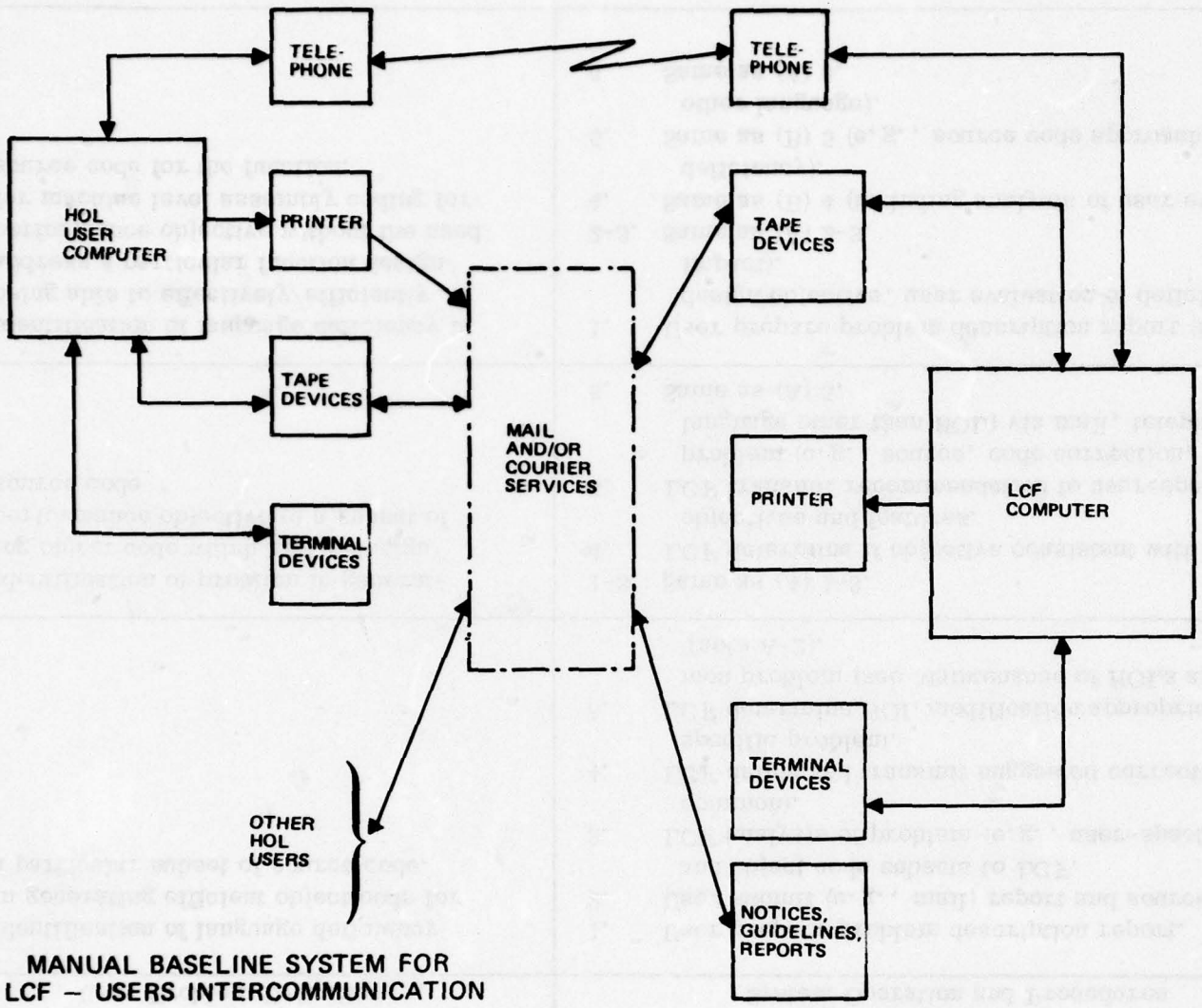

Figure A-1. Manual Baseline System for LCF - User Intercommunication

Table A-1. Manual Baseline System Definition - I (1 of 2)

User Problem Definition	System Operation and Procedures
(A) Identification of language deficiency in generating efficient object code for a particular subset of source code.	1. User prepare problem description report. 2. User submit (e.g., mail) report and source and object code subsets to LCF. 3. LCF analysis of problem (e.g., user-specific or common). 4. LCF define and transmit suggested correction to user specific problem. 5. LCF determine HOL modification appropriate to common problem (see Maintenance of HOLs and Tools - Table A-2).
(B) Identification of problem in generating object code which meets design/performance objective of a subset of source code	1-3. Same as (A) 1-3. 4. LCF determine if objective consistent with HOL objectives and features. 5. LCF transmit recommendation to user-specific problem (e.g., source, code correction, use language other than HOL) via mail, telephone. 6. Same as (A) 5.
(C) Identification of language deficiency in being able to effectively/efficiently address a particular function design/performance objective without the need for machine level assembly coding for source code for the function.	1. User prepare problem description report (including design objective, user evaluation of deficiency and impact). 2-3. Same as (A) 2-3. 4. Same as (B) 4 (including analysis of user evaluation deficiency). 5. Same as (B) 5 (e.g., source code approach, use other language). 6. Same as (A) 5.

Table A-1. Manual Baseline System Definition - I (2 of 2)

User Problem Definition	System Operation and Procedures
(D) Identification of problem of interfacing of code written in other languages assembly or other HOL for specific purposes (e.g., high efficiency take advantage of hardware specific features) with other code elements written in HOL.	1-5. Same as (B) 1-6.
(E) Identification of problem in understanding particular HOL feature and its application.	1. User call LCF to discuss understanding/interpretation of HOL feature and application. 2. LCF provide proper interpretation. 3. LCF determine if misunderstanding has been common (i.e., compare with other contracts). 4. LCF determine information dissemination appropriate to users (see Maintenance of HOLs and Tools - II, Table A-2, Item (E).

Table A-2. Manual Baseline System Definition - II (1 of 2)

Maintenance of HOLs and Tools	System Operation and Procedures
(A) Design and implementation of HOL/ tools modifications (e.g., corrections, updates, extensions).	1. LCF define/design modifications to HOL/tools to meet user problems, enhance or extend features of code generation/evaluation. 2. LCF implement HOL/tools modifications. 3. LCF generate modification test and validation (e.g., test code). 4. LCF test and validate modifications.
(B) Dissemination of HOL/tools modification to users.	1. LCF prepare compiler/tool modification materials package (i.e., compiler code modification description, code subset for insertion, correction or new compiler version tape, correction procedures, test data and procedures). 2. LCF transmit package to user(s) via mail, courier, LCF personnel delivery.
(C) Implementation/integration of HOL/ tools modifications in user systems.	1a. Modification of compiler/tool version at user system (i.e., by user personnel or LCF personnel) using code correction set and procedures in modification package, or 1b. Install new compiler/tool tape versions and test performance on previous user source codes and test data.

Table A-2. Manual Baseline System Definition - II (2 of 2)

Maintenance of HOLs and Tools	System Operation and Procedures
(D) Verification of proper implementation/ integration of HOL/tools modifications in user systems.	1a. Verify compiler/tool modification using test data and procedures in modification package (may be done by user or LCF personnel), or 1b. Install new compiler/tool tape versions and test performance on previous user source codes and test data.
(E) Dissemination of information (e.g., notices, user guidelines) on HOL/ tools modification.	1. LCF prepare user information material on HOL/tools modification. 2a. Incorporate information material in modification package, or 2b. Transmit information material independently (e.g., mail) to users.

Table A-3. Manual Baseline System Definition - III

Evaluation of Language Utilization	System Operation and Procedures
(A) Collection of user language by language analyzer on user system.	1. User operate language analyzer in conjunction with each program compilation. 2. HOL features utilization data collected on tape. 3. Data accumulated over appropriate reporting period.
(B) Transmission of collected data from user to LCF.	1. Accumulated usage data processed, statistics generated. 2a. Output printout or tape of statistics produced and prepared for shipment to LCF, or 2b. Unprocessed usage data tape prepared for shipment to LCF. 3. Transmit to LCF (e.g., mail).
(C) LCF accumulation, processing, and interpretation of language usage data from various users.	1. LCF receive and log input from each user. 2a. Prepare inputs to LCF system from user printouts or read user statistics tapes into LCF system, or 2b. Read unprocessed user tapes into LCF system. 3. Process user data (i.e., sort combine) and produce desired statistics.

Table A-4. Manual Baseline System Definition - IV (1 of 2)

Determination of Non-Standard Compiler Versions	System Operation and Procedures
(A) Generation and transmission of compiler test code(s).	1. LCF develop and generate compiler test code(s) in computer readable format. 2. LCF generate reference compilations using standard compiler version. 3a. Test code(s) transmitted to users (e.g., mail), or 3b. Test code(s) brought to user facilities by LCF verification personnel.
(B) Access to user HOL compiler.	1a. User retrieve compiler from library and mount on system, *or* 1b. LCF verification personnel retrieve compiler from user library for entry into user system.
(C) Compilation of test code(s) by user compiler version.	1. Test code(s) read into user system for compilation. 2. Test code(s) compilation results recorded. 3. Results records produced in printout format and machine readable tape format.
(D) Transmission of compilation(s) by user compiler to LCF.	1. Test code(s) compilation records transmitted to LCF (e.g., mail). 2. LCF verification personnel retrieve compilation record(s).

Table A-4. Manual Baseline System Definition - IV (2 of 2)

Determination of Non-Standard Compiler Versions	System Operation and Procedures
(E) LCF accumulation, evaluation, and determination of user compiler version deviation from standard.	1. User test code(s) compilations compared to reference compilations. 2. LCF personnel determine deviations from expected results, if any. 3. If deviations found, LCF personnel evaluate user compilations to determine probable nature of users compiler version deviations. 4. User notified of deviations determined and advised to refrain from deviations or to request modifications through channels.

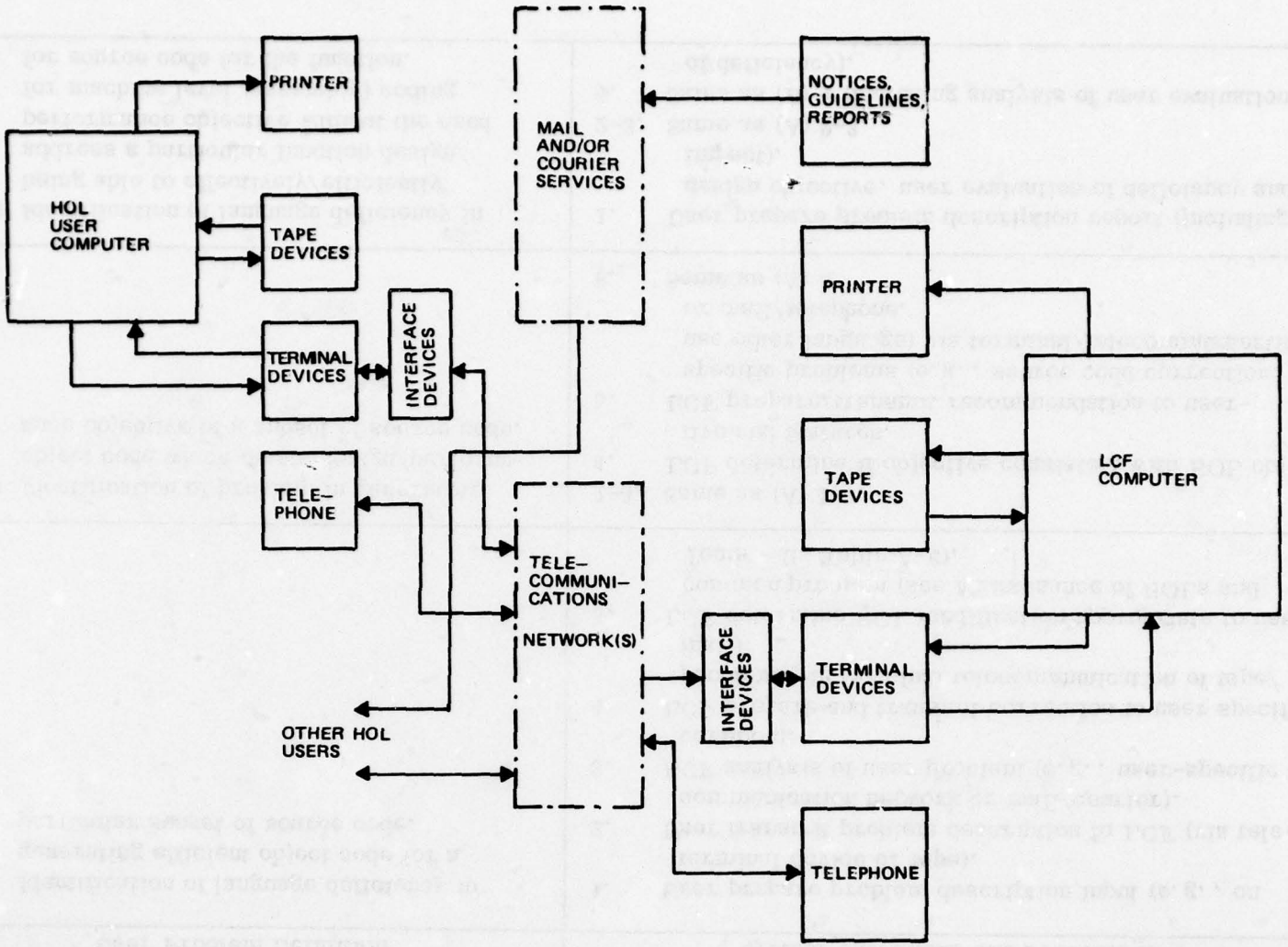

Figure A-2. Semi-Automated Telecommunications Interface System for LCF - User Intercommunications

Table A-5. Semi-Automated Telecommunications Interface System Definition - I (1 of 2)

User Problem Definition	System Operations and Procedures
(A) Identification of language deficiency in generating efficient object code for a particular subset of source code.	1. User prepare problem description input (e.g., on terminal device or tape). 2. User transmit problem description to LCF (via telecommunication network or mail/courier). 3. LCF analysis of user problem (e.g., user-specific or common). 4. LCF prepare and transmit correction to user specific problem (via terminal telecommunication of tape/mail). 5. LCF determine HOL modification appropriate to user common problem (see Maintenance of HOLs and Tools - II, Table A-6).
(B) Identification of problem in generating object code which meets design/performance objective of a subset of source code.	1-3. Same as (A) 1-3. 4. LCF determine if objective consistent with HOL objective and features. 5. LCF prepare/transmit recommendation to user-specific problems (e.g., source code correction, use other language) via terminal/telecommunication or mail/telephone. 6. Same as (A) 5.
(C) Identification of language deficiency in being able to effectively/efficiently address a particular function design/performance objective without the need for machine level (assembly) coding for source code for the function.	1. User prepare problem description report (including design objective, user evaluation of deficiency and impact). 2-3. Same as (A) 2-3. 4. Same as (B) 4 (including analysis of user evaluation of deficiency).

Table A-5. Semi-Automated Telecommunications Interface System Definition - I (2 of 2)

User Problem Definition	System Operations and Procedures
(C) (Continued)	5. Same as (B) 5 (e. g. , source code approach, use other language). 6. Same as (A) 5.
(D) Identification of problem of interfacing subsets of code written in other languages (assembly or other HOL) for specific purposes (e. g. , higher efficiency take advantage of hardware specific features) with other code elements written in HOL.	1-6. Same as (B) 1-6.
(E) Identification of problem in understanding particular HOL feature and its application.	1. User call LCF to discuss understanding/interpretation of HOL features and application. 2. LCF provide proper interpretation. 3. LCF determine if misunderstanding is common (e. g. , compare with other contracts). 4. LCF determine information dissemination appropriate to users (see Maintenance of HOLs and Tools - II, Table A-6, Item E).

Table A-6. Semi-Automated Telecommunications Interface System Definition - II (1 of 2)

Maintenance of HOLs and Tools	System Operation and Procedures
(A) Design and implementation of HOL/ tools modifications (e.g., corrections, updates, extensions).	1. LCF define/design modifications to HOL/tools to meet user problems, enhance or extend features of code generation/evaluation. 2. LCF implement HOL/tools modifications. 3. LCF generate modification test and validation (i.e., test codes). 4. LCF test and validate modifications.
(B) Dissemination of HOL/tools modifications to users.	1a. LCF prepare compiler/tools modification date (e.g., correction code subset, test codes), or 1b. LCF prepare complete new compiler/tool version tape. 2a. LCF transmit modification data to users (via terminal/ telecommunication), or 2b. LCF transmit modification data or new version tapes to users (via mail).
(C) Implementation/integration of HOL/ tools modification in user systems.	1a. User prepare verification run from LCF supplied compiler/tool version tape and modification test data, or 1b. User input LCF correction codes from existing compiler/tool and prepare verification run from corrected version and LCF supplied modification tool. 2. User initiate verification from terminal.

Table A-6. Semi-Automated Telecommunications Interface System Definition - II (2 of 2)

Maintenance of HOLs and Tools	System Operation and Procedures
(D) Verification of proper implementation/ integration of HOL/tools modifications in user systems.	1a. User verify compiler/tool modifications, test codes in modification package, or 1b. Users verify new version tapes using existing source code and test codes.
(E) Dissemination of information (e. g., notices, user guidelines) on HOL/ tools modifications.	1. LCF prepare user information material on HOL/tools modification. 2a. Information material incorporated in modification package transmitted to users (via terminal/ telecommunication or mail). 2b. Information material transmitted separately (via mail).

Table A-7. Semi-Automated Telecommunications Interface System Definition - III

Evaluation of Language Utilization	System Operations and Procedures
(A) Collection of user language usage by language analyzer on user system.	1. User operate language analyzer in conjunction with each program compilation. 2. HOL features utilization data collected on tape. 3. Data accumulated over appropriate reporting period. 4. Accumulated usage data processed and statistics generated.
(B) Transmission of collected data from user to LCF.	1a. Usage statistics output on normal computer tape, or 1b. Usage statistics output on terminal device. 2a. Computer output tape prepared and mailed to LCF, or 2b. Statistics data transmitted via terminal-to-terminal telecommunication.
(C) LCF accumulation, processing, and interpretation of language usage data from various users.	1a. LCF receive and log inputs mailed from each user, or 1b. LCF accumulate user data on terminal media. 2a. User data tapes read into LCF computer, or 2b. Accumulated data read into LCF computer from terminal. 3. Process user data (i.e., sort, combine) and produce desired statistics.

Table A-8. Semi-Automated Telecommunications Interface System Definition - IV (1 of 2)

Determination of Non-Standard Compiler Versions	System Operation and Procedures
(A) Generation and transmission of compiler test code(s).	1. LCF develop test code(s) and reference compilation(s). 2. Test code(s) output on data terminal media or magnetic tape. 3a. Test code(s) transmitted to users via terminal-to-terminal telecommunication, or 3b. Tape mailed to users.
(B) Access to user HOL compiler.	1. User retrieve compiler from library.
(C) Compilation of test code(s) by user compiler version.	1. Test code(s) read into user system from data terminal. 2. Test compilation(s) results recorded on terminal or magnetic tape.
(D) Transmission of compilation(s) by user compiler to LCF.	1a. Test compilation(s) results transmitted via terminal-to-terminal telecommunication, or 1b. Test compilation(s) results tape mailed to LCF.

Table A-8. Semi-Automated Telecommunications Interface System Definition - IV (2 of 2)

Determination of Non-Standard Compiler Versions	System Operation and Procedures
(E) LCF accumulation, evaluation, and determination of user compiler version deviation from standard.	1a. Test compilation(s) results accumulated on terminal media, or 1b. Test compilation(s) tapes received and logged. 2. Test compilation(s) results read into computer from data terminal for comparison with reference compilation and detection of deviations. 3. LCF evaluate deviations found to determine nature of probable user compiler version deviations from standard.

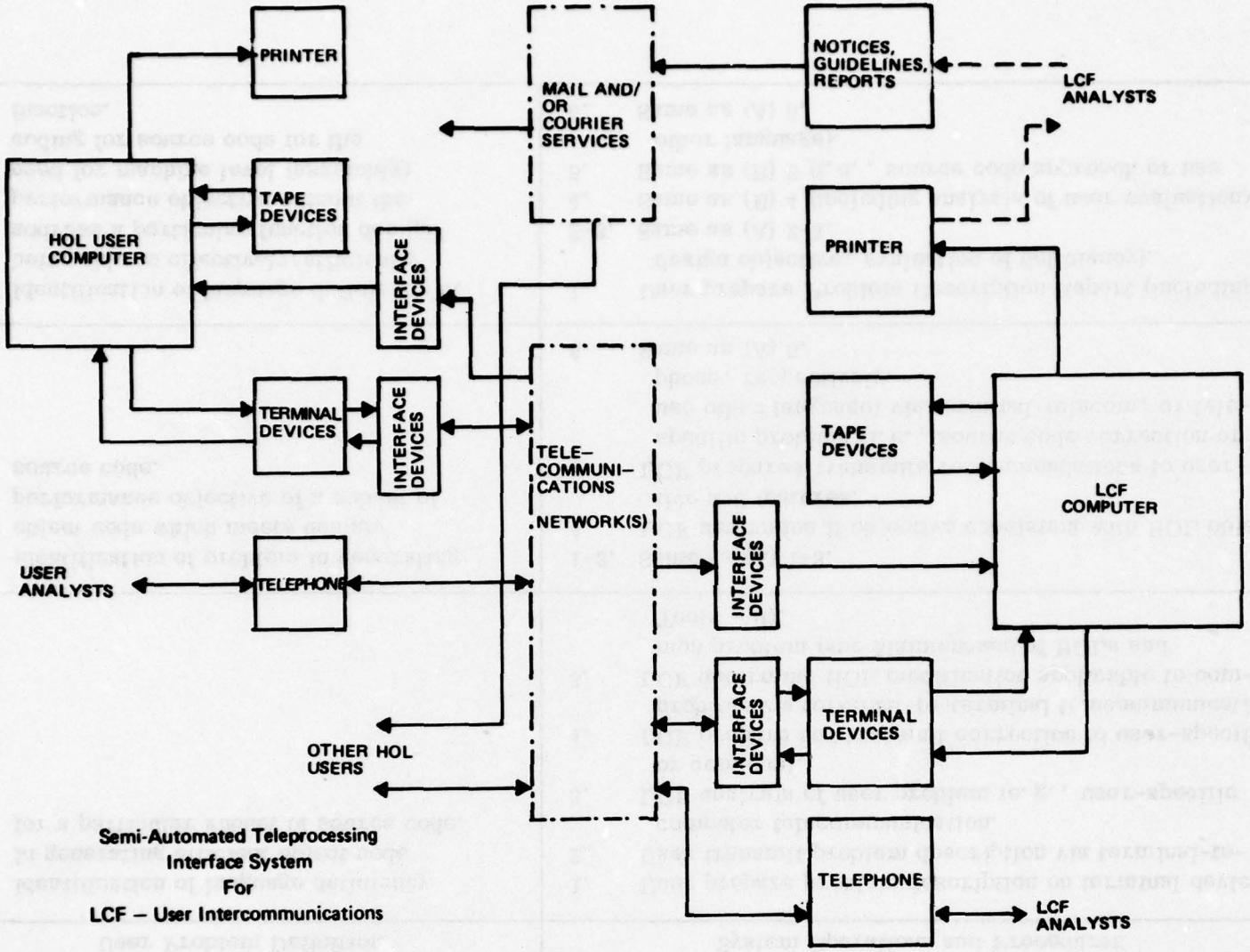

Figure A-3. Semi-Automated Teleprocessing Interface System for LCF - User Intercommunications

Table A-9. Semi-Automated Teleprocessing Interface System Definition - I (1 of 2)

User Problem Definition	System Operations and Procedures
(A) Identification of language deficiency in generating efficient object code for a particular subset of source code.	1. User prepare problem description on terminal device. 2. User transmit problem description via terminal-to-computer telecommunication. 3. LCF analysis of user problem (e.g., user-specific or common). 4. LCF prepare and transmit correction to user-specific problem via terminal-to-terminal telecommunication. 5. LCF determine HOL modification applicable to common problem (see Maintenance of HOLs and Tools - II).
(B) Identification of problem in generating object code which meets design/performance objective of a subset of source code.	1-3. Same as (A) 1-3. 4. LCF determine if objective consistent with HOL objective and features. 5. LCF prepares/transmits recommendations to user-specific problem (i.e., source code correction or use other language) via terminal/telecom, or telephone, respectively. 6. Same as (A) 5.
(C) Identification of language deficiency in being able to effectively/efficiently address a particular function design/performance objective without the need for machine level (assembly) coding for source code for the function.	1. User prepare Problem Description Report (including design objective, evaluation of deficiency). 2-3. Same as (A) 2-3. 4. Same as (B) 4 (including analysis of user evaluation). 5. Same as (B) 5 (i.e., source code approach or use other language). 6. Same as (A) 5.

Table A-9. Semi-Automated Teleprocessing Interface System Definition - I (2 of 2)

User Problem Definition	System Operations and Procedures
(D) Identification of problem of interfacing subsets of code written in other languages (assembly or other HOL) for specific purposes (e.g., higher efficiency, take advantage of hardware specific features) with other code elements written in HOL.	1-6. Same as (B) 1-6.
(E) Identification of problem in understanding particular HOL feature and its application.	1. User call LCF to discuss understanding/interpretation of HOL features and application. 2. LCF provide proper interpretation. 3. LCF determine if misunderstanding is common. 4. LCF determine if information dissemination appropriate to users (see Maintenance of HOLs and Tools - II, Table A-10, Item E).

Table A-10. Semi-Automated Teleprocessing Interface System Definition - II (1 of 2)

Maintenance of HOLs and Tools	System Operations and Procedures
(A) Design and implementation of HOL/ tools modifications (e.g., corrections, updates, extensions).	1. LCF define/design modifications to HOL/tools to meet user problems, enhance or extend features for code generation/compilation/analysis. 2. LCF generate correction codes and procedures. 3. LCF generate modification test and validation codes and procedures. 4. LCF implement modifications to own version. 5. LCF test and validate modifications and modification/ test procedures.
(B) Dissemination of HOL/tools modifications to users.	N/A
(C) Implementation/integration of HOL/ tools modifications in user systems.	1. LCF call user to read compiler and/or tools into system. 2. LCF access user system via terminal. 3. Read correction code(s) into user system via terminal. 4. Initiate compiler generator tool or tool modification software via terminal.
(D) Verification of proper implementation/ integration of HOL/tools modifications in user systems.	1. Maintain access connection with user system. 2. Read in test code(s) via terminal. 3. Initiate modified compiler or tool via terminal. 4. User computer output test code compilation/results on LCF terminal. 5. LCF compare compilation/results output with reference standard to verify proper modification.

Table A-10. Semi-Automated Teleprocessing Interface System Definition - II (2 of 2)

Maintenance of HOLs and Tools	System Operations and Procedures
(E) Dissemination of information (e.g., notices, user guidelines) on HOL/ tools modifications.	1. LCF prepare user information material on HOL/tools modifications. 2. Material transmitted via mail.

Table A-11. Semi-Automated Teleprocessing Interface System Definition - III

Evaluation of Language Utilization	System Operations and Procedures
(A) Collection of user language usage by language analyzer on user system.	1. User operate language analyzer in conjunction with each program compilation. 2. HOL features utilization data collected on tape. 3. Data accumulated over appropriate reporting period. 4. Accumulated usage data processed and statistics generated.
(B) Transmission of collected data from user to LCF.	1. Usage data statistics output on terminal media. 2a. Statistics data transmitted to LCF via terminal-to-terminal telecom. 2b. Statistics data transmitted to LCF via terminal-to-computer telecom.
(C) LCF accumulation, processing, and interpretation of language usage data from various users.	1a. LCF accumulate user data on terminal media, or 1b. LCF accumulate user data on computer magnetic tape. 2a. Accumulated data read into computer from terminal, or 2b. Accumulated data read in from computer magnetic tape. 3. Process user data (i.e., sort, combine) and produce desired statistics.

Table A-12. Semi-Automated Teleprocessing Interface System Definition - IV

Determination of Non-Standard Compiler Versions	System Operations and Procedures
(A) Generation and transmission of compiler test code(s).	1. LCF develop test code(s) and reference compilations. 2a. Test code(s) output on terminal media. or 2b. Test code(s) output on computer magnetic tape.
(B) Access to user HOL compiler.	1. LCF call user to read compiler into computer system. 2. LCF access user system via terminal.
(C) Compilation of test code(s) by user compiler version.	1. LCF read test code(s) into user system via terminal. 2. LCF initiate compiler operation.
(D) Transmission of compilation(s) by user compiler(s) to LCF.	1. User computer output test code(s) compilation to LCF terminal. 2. Test compilation logged.
(E) LCF accumulation, evaluation, and determination of user compiler version deviation from standard.	1. Test code(s) compilation read into computer. 2. LCF compare test compilation with reference standard. 3. LCF evaluate deviations to determine nature of probable deviations in user compiler version.

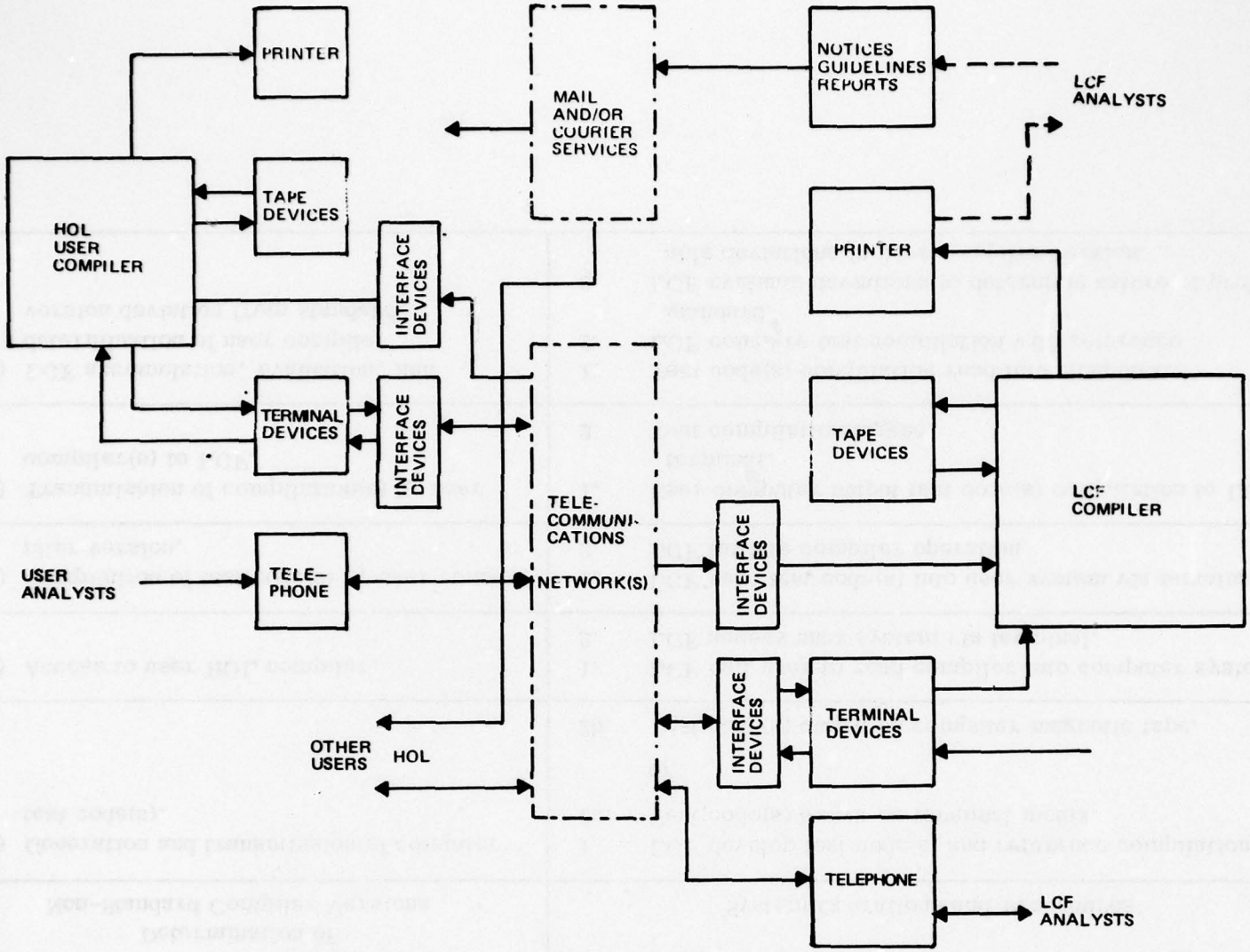

Figure A-4. Automated Telecommunications/Teleprocessing Interface System for LCF - User Intercommunications

Table A-13. Automated Telecommunication/Teleprocessing Interface System Definition - I (1 of 2)

User Problem Definition	System Operations and Procedures
(A) Identification of language deficiency in generating efficient object code for a particular subset of source code.	1. User computer prepare problem description output data. 2. User direct transmission of problem description to LCF terminal. 3. LCF analysis of user problem (e.g., user-specific or common). 4. LCF prepare and transmit correction to user-specific problem via computer or terminal-terminal telecom. 5. LCF determine HOL modifications applicable to user problem (see Maintenance of HOLs and Tools - II, Table A-14).
(B) Identification of problem in generating object code which meets design/performance objective of a subset of source code.	1-3. Same as (A) 1-3. 4. LCF determine if objective consistent with HOL objective and features. 5. LCF prepare/transmit recommendations to user specific problem (i.e., source code correction or use other language) to user terminal or via telephone, respectively. 6. Same as (A) 5.
(C) Identification of language deficiency in being able to effectively/efficiently address a particular function design/performance objective without the need for machine level (assembly) coding for source code for the function.	1. User prepare problem description report (including design objection, evaluation of deficiency). 2-3. Same as (A) 2-3. 4. Same as (B) 4 (including analysis of user evaluation). 5. Same as (B) 5 (i.e., source code approved or use other language. 6. Same as (A) 5.

Table A-13. Automated Telecommunication/Teleprocessing Interface System Definition - I (2 of 2)

User Problem Definition	System Operations and Procedures
(D) Identification of problem of interfacing subsets of code written in other languages (assembly or other HOL) for specific purposes (e.g., higher efficiency, take advantage of hardware specific features) with other code elements written in HOL.	1-6. Same as (B) 1-6.
(E) Identification of problem in understanding particular HOL feature and its application.	1. User call LCF to discuss understanding and interpretation of HOL features and application. 2. LCF provide proper interpretation. 3. LCF determine if misunderstanding is common. 4. LCF determine if information dissemination appropriate to users (see Maintenance of HOLs and Tools - II, Table A-14, Item E).

Table A-14. Automated Telecommunication/Teleprocessing Interface System Definition - II (1 of 2)

Maintenance of HOLs and Tools	System Operations and Procedures
(A) Design and implementation of HOL/ tools modification (e.g., corrections, updates, extensions).	1. LCF define/design modifications to HOL/tools to meet user problems, enhance or extend features for code generation/compilations/analysis. 2. LCF generate correction codes and modification procedures. 3. LCF generate modification test and validation codes and procedures. 4. LCF implement modifications to own version. 5. LCF test and validate modifications and modification/ test procedures.
(B) Dissemination of HOL/tools modifications to users.	N/A
(C) Implementation/integration of HOL/ tools modifications in user systems.	1. LCF call user to read compiler and/or tools into system. 2. LCF access user system. 3. Read correction code(s) into user system under terminal control. 4. Initiate compiler generator or modification software.
(D) Verification of proper implementation/ integration of HOL/tools modification in user systems.	1. Maintain connection with user system. 2. Read in test code(s) under terminal control. 3. Initiate modified compiler or tool. 4. User computer transmit test code compilation/ operation results to LCF computer. 5. LCF system compare compilation/operation results with reference standard to verify proper modification.

Table A-14. Automated Telecommunication/Teleprocessing Interface System Definition - II (2 of 2)

Maintenance of HOLs and Tools	System Operations and Procedures
(E) Dissemination of information (e. g. , notices, user guidelines) on HOL/ tools modifications.	1. LCF prepare user information material on HOL/ tool modifications. 2. Material transmitted via mail.

Table A-15. Automated Telecommunication/Teleprocessing Interface System Definition - III

Evaluation of Language Utilization	System Operations and Procedures
(A) Collection of user language usage by language analyzer on user system.	1. User operate language analyzer in conjunction with each program compiler. 2. Resulting data output on computer magnetic tape. 3. Data accumulated over appropriate reporting period.
(B) Transmission of collected data from user to LCF.	1. User access LCF computer or vice versa. 2. Accumulated data transmitted computer-to-computer.
(C) LCF accumulation, processing, and interpretation of language usage data from various users.	1. LCF accumulate data from all users on computer tape. 2. Accumulated data read in computer. 3. Process data (i.e., sort, combine) and produce statistics.

Table A-16. Automated Telecommunication/Teleprocessing Interface System Definition - IV

Determination of Non-Standard Compiler Versions	System Operations and Procedures
(A) Generation and transmission of compiler test code(s).	1. LCF develop test code(s) and reference compilations. 2a. Test code(s) stored on LCF computer tape or other memory, or 2b. Test code(s) output on LCF terminal media. 3. Reference compilations stored on computer tape or in disk memory.
(B) Access to user HOL compiler.	1. LCF call user to read compiler into computer system. 2. LCF access user system.
(C) Compilation of test code(s) by user compiler version.	1. LCF read test code(s) in user system under terminal control. 2. LCF initiate compiler operation under terminal control.
(D) Transmission of compilation(s) by user compiler to LCF.	1. User computer transmit test code(s) compilation to LCF computer.
(E) LCF accumulation, evaluation, and determination of user compiler version deviation from standard.	1. User test code(s) compilation compared to reference compilation. 2. LCF evaluate deviations from reference standard to determine nature of probable deviations in user compiler version.

APPENDIX B - INSTRUCTIONS FOR COMPLETING

DA FORM 3207-R (FIGURE B-1)

COST ANALYSIS WORKSHEET

For use of this form, see AR 235-5; the proponent agency is Office of the Deputy Chief of Staff for Logistics.

NAME OF INSTALLATION/ACTIVITY	FUNCTION			
COST ELEMENTS	FIRST YEAR OF OPERATION	SECOND YEAR OF OPERATION	THIRD YEAR OF OPERATION	FOURTH AND FOLLOWING YEARS OF OPERATION
CONTRACT OPERATIONS				
1. CONTRACT COST *(Price paid to supplier)*				
2. TRANSPORTATION				
3. CONTRACT ADMINISTRATION AND RELATED COSTS				
4. GOVERNMENT FURNISHED MATERIALS AND SUPPLIES				
5. CONTRACTOR USE OF GOVERNMENT OWNED EQUIPMENT AND FACILITIES				
6. REHABILITATION, MODIFICATION OR EXPANSION OF GOVERNMENT OWNED EQUIPMENT AND FACILITIES				
7. INCENTIVE OR PREMIUM COSTS				
8. STANDBY MAINTENANCE COST				
9. OTHER COSTS				
9A. TOTAL				
GOVERNMENT OPERATIONS				
10. MILITARY PERSONNEL SERVICES				
11. CIVILIAN PERSONNEL SERVICES				
12. OTHER PERSONNEL COSTS				
13. MATERIALS, SUPPLIES, UTILITIES AND OTHER SERVICES				
14. MAINTENANCE AND REPAIR				
15. OVERHEAD COSTS				
15A. SUBTOTAL *(Sum of elements 10 through 15)*				
16. FEDERAL TAXES				
17. DEPRECIATION				
18. INTEREST				
19. INSURANCE				
20. OTHER INDIRECT COSTS				
20A. TOTAL				
GOVERNMENT OPERATIONS - OTHER *(ISS/IDS/IAS)*				
21. REIMBURSABLE COSTS				
22. ADMINISTRATION COSTS				
23. TRANSPORTATION				
24. MATERIALS, SUPPLIES, UTILITIES AND OTHER SERVICES				
25. PERSONNEL COSTS				
26. OTHER COSTS				
26A. TOTAL				

DA FORM 3267-R, 1 Nov 72 EDITION OF 1 NOV 69 IS OBSOLETE. *(Paper size: 10½" x 8"; Image size: 9-9/10" x 7-2/6")*

Figure B-1. Cost Analysis Worksheet

Line	Enter—
1	The price paid to the current contractor (contract cost less allowable discounts) for the product or service being evaluated, or if not currently contracted, the anticipated price from commercial sources (Informational Quotations). a. "Informational Quotations" may be used in the cost analysis (when current contract data is not available) if there is reasonable assurance that the contractor is capable and willing to provide the product or service for the quoted price. See ASPR 1-309 for conditions under which contractors may be solicited for quotations for information or planning purposes. b. In some instances, the "going contract price" paid for the same product or service by other Government installations in the same geographical area may be used. This method of costing contract performance should be used with discretion since, in most cases, specifications for products or services vary considerably from installation to installation. If this method is employed, backup documentation must be provided to substantiate the similarity of product or service work specifications. Installations should avail themselves of the General Services Administration, Small Business Administration, Purchasing Offices, Defense Contract Services, etc., in attempting to obtain comparable contract costs. c. "Estimating" contractual cost based on equating contractor labor-hours, methods and techniques, tools and materials to those of the Government is the least acceptable method of determining contract cost. It should only be used if the above described sources for contract data are not available or price quotations from solicited commercial sources are determined to be unreasonable. If the "estimated" contract cost technique is utilized, full documentation must be provided, indicating methodology used in arriving at the estimated cost. In addition, the rationale for the determination that informational quotations are "unreasonable" should be included in the documentation. d. If, after making a decision to contract a function, firm offers are received which are higher than the cost to perform the function in-house, reconsideration of the decision is necessary.
2	Any transportation charges not included elsewhere in the contract cost.
3	Total of all contract administration and related costs which the Government must pay because of the existence of the contract, but which it would not otherwise have to pay. This will include, but will not necessarily be limited to, costs for preparation of specifications, bid invitations, pre-award surveys, contract negotiation including award, inspection and acceptance, and contract administration subsequent to award. Only the additional/incremental administration and related costs will be entered in this cost element if the contract is administered by the installation. If the contract is administered by another agency, enter *only* those costs for which the agency requires reimbursement.
4	Actual cost to the Government of materials and supplies consumed by the contractor (including any costs of transportation, storage, etc.), which may be involved, as described in line 13.
5	Reduction in procurement costs to be made to cover contractor use of Government-furnished equipment and facilities. See ASPR 7-702.12 for rental factors to be applied for contractor use of Government-furnished equipment and facilities. These factors will be applied in determining the reduction in procurement costs.

Line	Enter—
6	Cost to the Government of rehabilitating, modifying, or expanding Government-owned equipment or facilities provided to the contractor.
7	Costs caused by incentive or premium provisions in the contract.
8	Cost of preparing a Government facility for standby status, and the annual cost of its standby maintenance if this results from the commercial procurement action.
9	Additional costs which would result from commercial procurement and which are not covered elsewhere. Termination costs for Government personnel such as premature retirement causing a significant increase in the retirement costs to the Government, severance pay, home-owner's assistance, and moving/relocation expenses which will actually be paid *solely* because a Government in-house activity is discontinued will be included when appropriate. Terminal leave costs are not allowed.
9a	Sum of lines 1 through 9.
10	Cost of all military personnel (including supervisory, administrative, support and service personnel) who are for work measurement or cost accounting purposes identified to the function. This cost will be computed in accordance with AR 37-108 and DA Pam 37-6.
11	*a.* Cost of civilian authorizations which are for work measurement or cost accounting purposes identified to the function. The cost of the civilian positions will be gross annual pay as shown in current pay tables, plus the Government's contribution for civilian retirement (or social security if applicable instead of civilian retirement), disability, health, and life insurance. These contributions should be determined by multiplying the following percentage factors to the base pay:

Retirement and disability (for employees under Civil Service retirement)*	7.14%
Health	1.0%
Life insurance	.3%

*A lower factor for retirement and disability should be applied if a part of the work force would be permanently subject to the Social Security Act, rather than the Civil Service retirement system. The current social security rate will be used in making cost studies.

b. If labor costs are determined on the basis of direct labor hours applied, the civilian pay rate increased by 29.34 percent to include leave and other benefits would be used. The 29.34 percent acceleration of civilian pay represents the average cost of leave (20.9 percent for sick leave taken and for annual, holiday, and other paid leave accruals), plus 8.44 percent for average Government contribution for other benefits.

12	Sum of personnel costs which pertain to performance of the function under consideration and which are not included in lines 10 or 11, such as travel, per diem and moving expenses, cost of living and uniform allowances, initial and recurring costs of personnel training.
13	All costs to the Government of supplies and materials used in providing a product or service. Include the costs incurred by the installation for transportation, handling, storage, custody and protection of these materials and supplies, and the cost of utility services including specifically, electric power, gas, water, and communications related to the function. Initial startup costs for new activities will also be included. Cost of material and supplies will include consideration for reasonable overruns, spoilage,

Line	Enter—
	or defective work. To cover central procurement and supply system costs above the installation level, a factor of 5 percent should be added to the total cost of materials and supplies obtained through the Department of Defense Depot Supply System. The 5 percent cost factor should not be applied to items procured locally or through GSA.
14	Cost of maintenance and repair to the buildings, structures, grounds, and equipment used by the function involved in producing the goods or services. Do not include capital improvements. Engineering estimates may be used to compute proper proportions of cost chargeable. Include only those maintenance and repair expenses directly attributable to the in-house performance of the service. Any maintenance and repair expense that would continue whether the service under study were procured or were performed in-house should be excluded from in-house cost of performance for this analysis.
15	Additional costs which are or would be incurred at the installation level because of performing the function in-house. These include the additional (incremental) costs of general overhead, such as finance and accounting, personnel, legal, local procurement, medical services, management, direction, and administration above the organization performing the function. This excludes costs of performing or directly supporting the function recorded on lines 10 through 14. *a.* If the operation is currently performed in-house, the amount to be reported on line 15 represents only those costs which can be identified to the support of the operation and which would not be necessary if the function were not being performed. The amount represents the actual dollar savings of overhead costs that would be realized if the operation were discontinued. *b.* If the operation is not being performed in-house, i.e., not currently being performed, or being performed by contract, the amount to be entered on line 15 will represent those additional overhead costs that would be incurred by commencement of an in-house operation.
15a	Sum of lines 10 through 15.
16	*a.* Federal taxes as appropriate for each industry. These include income tax and other Federal tax revenue (except Social Security taxes) which would be receive from the commercial firm (but not from its individual employees or stockholders) if the product or service is obtained through commercial sources. To compute these taxes, use the functional area cost factor listed below. The functional codes are from appendix A. These rates are based on ratios of taxes to income by industry. To use the functional area cost factors; multiply the cost shown on line 1 by the percentage factor listed for the appropriate functional code. The result is the tax estimate.

Functional area	*Cost factor*
J, K, M, S, W, T (except S725 thru S730, T809)	1.83%
S725 thru S730, T809	10.50%
X931, 936, 940, 942, 943, 944	2.54%
X932, 934	1.52%
X933, 938, 939, 937	3.46%
X935	5.63%
X941	4.75%
Z	1.83%

b. The actual experience of the contractor under consideration may, if available, be used to calculate tax estimates.

c. If the factors in *a* above are not applicable because of special circumstances, estimates of corporate incomes may be based upon the earnings experience of the industry, if available; but if such data are not available, the

Line	Enter—
	Quarterly Financial Report of Manufacturing Corporations, published by the Federal Trade Commission and the Securities and Exchange Commission may be consulted. Alternatively, the Internal Revenue Service Publication No. 16, *Corporation Income Tax Returns* may be used. Assistance from appropriate Government regulatory agencies may be obtained in estimating taxes from regulated industries.
17	*a.* New or additional facilities or equipment. Depreciation should be computed as a cost for any new or additional facilities or equipment, and for any rehabilitation, modification or expansion of existing facilities or equipment which will be required if a Government activity is started or continued. In computing the depreciation cost of new or additional facilities or equipment to be acquired if a Government activity is started or continued, and in determining the comparative costs under lease-purchase alternatives, *appropriate recognition* should be given to estimated salvage or residual values of the facilities or equipment. The Internal Revenue Service publication, Depreciation: *Guidelines and Rules* may be used in computing depreciation. A condensed listing of these depreciation rates is provided in figure 4-2. However, these rates are maximums to be used only for reference purposes and only when more specific depreciation rate are not available. Accelerated depreciation rates permitted in some instance by the Internal Revenue Service will not be used.
	b. Existing equipment or facilities ("opportunity costs"). Depreciation *will not* be allocated for facilities acquired by the Government before the cost comparison study is started. However, if reliance upon a commercial source will cause Government-owned equipment or facilities to become available for other Federal use or for disposal as surplus, the cost comparison analysis should include as a cost in the first year of operation of the Government activity an appropriate amount based upon the estimated current market value of such equipment or facilities. (Footnote and explain.) This amount represents an opportunity cost, which is the money the Government would lose by continuing this activity with its existing equipment and facilities. If the Government would discontinue the function, it would have an opportunity to recoup certain moneys for its equipment and facilities.
18	Computed interest for any new or additional capital to be invested by the Government. This entry is used to estimate the interest the Government would have to pay when borrowing to make the capital investment. Interest for the first year of cost comparison will be computed on the full value of the new or additional capital investment. Interest for subsequent years will be computed on the value of the capital investment reduced by annual depreciation. The rate of interest will be the current interest for long term Treasury obligations. Yield rates are reported in the current issue of the Treasury Bulletin, Table 1, *Average Yields of Treasury and Corporate Bonds by Periods*, and will be used in these computations regardless of any rates of interest which may be used by the agency for other purposes.
19	Costs incurred or to be incurred by the activity which results from uninsured losses caused by fire or other hazards, insurance premiums and settlement of loss and damage claims, and the cost of claims paid through the Bureau of Employees' Compensation. To simplify calculation of these total insurance costs, they should be estimated by applying a factor of 0.3 percent of all Government costs shown on line 15a.
20	Additional indirect costs incurred or to be incurred because commercial procurement is not used. These indirect costs consist of various central administrative services *above the installation level*, such as centralized accounting, personnel, and legal assistance or other Government-wide ser-

Line	Enter—
	vices of such organizations as the Public Buildings Service and the General Services Administration. It is not always feasible to determine the extent to which the costs of these types of central services should be allocated to a Government commercial or industrial activity on an individual basis. To cover these services, a cost factor of 2 percent may be applied to line 15a and the result will be entered on line 20 of the worksheet. In lieu of the 2-percent factor, a higher or lower amount may be used in unusual cases provided the basis for the substitution is fully justified in the cost comparison.
20a	Sum of lines 10 through 15 and 16 through 20.
21	Actual reimbursable costs or, in the case of a proposed new support agreement, the anticipated reimbursable costs for products/services furnished by another installation, another service, or another governmental department or agency.
	Note. All entries recorded in lines 22 through 26 will represent those additional costs incurred by the installation receiving support not included in line 21 and which it would not have incurred without the existence of the support agreement.
22	Actual or anticipated administrative costs which the installation incurs or will incur because of the existence of a support agreement with another installation.
23	Actual or anticipated transportation and travel costs incurred by the installation receiving support.
24	Actual or anticipated costs incurred by the receiving installation for materials, supplies, utilities and other services furnished to and used by the supporting installation in producing the product or performing the service.
25	Actual or anticipated costs of personnel assigned to the supporting installation, if its manpower requirements are provided on a joint staff basis.
26	Any additional costs, not included in lines 21 through 25, which are or will be incurred by the installation receiving support.
26a	Sum of lines 21 through 26.

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METRIC SYSTEM

BASE UNITS:

Quantity	Unit	SI Symbol	Formula
length	metre	m	...
mass	kilogram	kg	...
time	second	s	...
electric current	ampere	A	...
thermodynamic temperature	kelvin	K	...
amount of substance	mole	mol	...
luminous intensity	candela	cd	...

SUPPLEMENTARY UNITS:

plane angle	*radian*	rad	...
solid angle	steradian	sr	...

DERIVED UNITS:

Acceleration	metre per second squared	...	m/s
activity (of a radioactive source)	disintegration per second	...	(disintegration)/s
angular acceleration	radian per second squared	...	rad/s
angular velocity	radian per second	...	rad/s
area	square metre	...	m
density	kilogram per cubic metre	...	kg/m
electric capacitance	farad	F	A·s/V
electrical conductance	siemens	S	A/V
electric field strength	volt per metre	...	V/m
electric inductance	henry	H	V·s/A
electric potential difference	volt	V	W/A
electric resistance	ohm		V/A
electromotive force	volt	V	W/A
energy	joule	J	N·m
entropy	joule per kelvin	...	J/K
force	newton	N	kg·m/s
frequency	hertz	Hz	(cycle)/s
illuminance	lux	lx	lm/m
luminance	candela per square metre	...	cd/m
luminous flux	lumen	lm	cd·sr
magnetic field strength	ampere per metre	...	A/m
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb/m
magnetomotive force	ampere	A	...
power	watt	W	J/s
pressure	pascal	Pa	N/m
quantity of electricity	coulomb	C	A·s
quantity of heat	joule	J	N·m
radiant intensity	watt per steradian	...	W/sr
specific heat	joule per kilogram-kelvin	...	J/kg·K
stress	pascal	Pa	N/m
thermal conductivity	watt per metre-kelvin	...	W/m·K
velocity	metre per second	...	m/s
viscosity, dynamic	pascal-second	...	Pa·s
viscosity, kinematic	square metre per second	...	m/s
voltage	volt	V	W/A
volume	cubic metre	...	m
wavenumber	reciprocal metre	...	(wave)/m
work	joule	J	N·m

SI PREFIXES:

Multiplication Factors	Prefix	SI Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto*	h
10 = 10^{1}	deka*	da
0.1 = 10^{-1}	deci*	d
0.01 = 10^{-2}	centi*	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	*nano*	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

* To be avoided where possible.

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RADC plans and conducts research, exploratory and advanced development programs in command, control, and communications (C^3) activities, and in the C^3 areas of information sciences and intelligence. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.